EngOpt 2012

3rd International Conference on Engineering Optimization

Rio de Janeiro, Brazil, July 1-5, 2012

Books of Abstracts and CD-ROM Proceedings of EngOpt 2012, 3rd International Conference on Engineering Optimization held at Rio de Janeiro from July 1 to 5 of 2012. EngOpt 2012 was organized by the Mechanical Engineering Program of COPPE, Alberto Luis Coimbra Institute of the Federal University of Rio de Janeiro. EngOpt 2012 was co-sponsored by ISSMO – International Society for Structural and Multidisciplinary Optimization, MathProg – Mathematical Programming Society, EUROPT – EURO Working Group on Continuous Optimization and ABCM – Brazilian Society of Mechanical Sciences and Engineering.

EngOpt 2012 was partly suported by:

CNPq, Brazilian Research Council

CAPES, Brazilian Ministry of Education

FAPERJ, Rio de Janeiro's State Research Council

FINEP, Brazilian Innovation Agency

ELETROBRAS

PETROBRAS

EngOpt 2012

3rd International Conference on Engineering Optimization

BOOK OF ABSTRACTS

Edited by

José Herskovits

OptimizE – Engineering Optimization Lab
COPPE/Mechanical Engineering Program
Federal University of Rio de Janeiro, Brazil
http://www.optimize.ufrj.br

ISBN 978-85-7650-344-6

Conference Secretariat
Mrs. Arminda Lobo
engopt@optimize.ufrj.br
Silvio Britto
engopt@optimize.ufrj.br

Webmaster
WGE Systems Ltd.
723, Francisco Antonio Oliveira Street, 38408-258, Uberlandia, MG, Brazil.
Phone: 55 34 3216-5508 ,
contato@swge.com.br

Published by E-papers Serviços Editoriais Ltda
http://www.e-papers.com.br
phone 55 21 2273-0138
atendimento@e-papers.com.br

Engopt 2012

Organized by

COPPE/UFRJ – Alberto Luis Coimbra Institute
Graduate School in Engineering, Federal University of Rio de Janeiro

Sponsoring Societies

ABCM – Brazilian Society of Mechanical Sciences and Engineering
EUROPT – EURO Working Group on Continuous Optimization
ISSMO – International Society for Structural and Multidisciplinary Optimization
MOS – Mathematical Optimization Society

Organizing Committee

José Herskovits – General Chairman
Mecanical Engineering Program – COPPE/UFRJ

Miguel Aroztegui
UFRN, Brazil

Elmer Bazan
UFRJ, Brazil

Alfredo Canelas
UDELAR, Uruguay

Grigori Chapiro
UFJF, Brazil

Antoli Leontiev
UFRJ, Brazil

Sandro Mazorche
UFJF, Brazil

Mario Tanaka Filho
UFOPA, Brazil

International Organizing Committee

Kyung K. Choi
The University of Iowa, USA

Carlos A. Mota Soares
Technical University of Lisbon, Portugal

Helcio R. B. Orlande
Federal University of Rio de Janeiro, Brazil

E. Schnack
Universität Karlsruhe, Germany

Argimiro R. Secchi
Federal University of Rio Grande do Sul, Brazil

Ole Sigmund
President of ISSMO
Technical University of Denmark, Lyngby

Stephen Wright
Vice chair, Mathematical Optimization Society
University of Wisconsin, United States

Advisory Board

International Scientific Committee

P. Kobis, Czestochow , Poland
E. Kostina, Marburg , Germany
S. Koziel, Reykjavik , Iceland
B. Lazarov, Lyngby , Denmark
R.P. Leal, Coimbra Portugal
C. Leão, Braga , Portugal
T. Lehmann, Berlin , Germany
L. Leifsson, Reykjavik , Iceland
J. Lellep, Tartu , Estonia
A. C. C. Lemonge, Juiz de Fora , Brazil
J.F.A. Madeira, Lisbon , Portugal
N. Maïzi, Sophia Antipolis , France
J. Majak, Tallinn , Estonia
M. Marcovecchio, Lisbon , Portugal
A. Marta, Lisbon , Portugal
N. F.M. Martins, Lisbon , Portugal
D. Materna, Dortmund , Germany
I. Merta, Vienna , Austria
J. Michopoulos, Washington , United States
Z. Mrós, Warsaw , Poland
S. Mussati, Santa Fé , Argentina
A. NASTASE., Aachen , Germany
C. Neipp, Alicante , Spain
N. Obregón, Bogota , Colombia
G. Papa, Ljubljana , Slovenia
P. Y. Papalambros, Ann Arbor , United States
S. Parashar, Livornia , United States
C. S. Pedamallu, Ipswich , United States
J. Peethambaran, Lisbon , Portugal
F. Pereira, , Brazil
E. A. Pérez , Madrid , Spain
V. Picheny, Paris , France
H. Pina, Lisbon, Portugal
T. Pinto-Varela, Lisbon , Portugal
A. Raich, Easton , United States
S. Rajan, Tempe , United States
S. Relvas , Lisbon , Portugal
A. Renaud, Paris , France
A. Rocha, Braga , Portugal
J. Roche, Vandoeuvre Les Nancy , France
H. Rodrigues, Lisbon , Portugal
R. Schultz, Duisburg-Essen , Germany
A. Seifi, Tehran , Iran
A. P. Seyranian, Moscow , Russia
S. Shahpar, Derby , United Kingdon
Y. Shimizu, Toyohashi , Japan
J. Sienz, Swansea , United Kingdon
O. Sigmund, Lyngby , Denmark
R. L. Smith, Ann-Arbour , United States
T. Sokol, Warsaw , Poland
L. C. Sousa, Porto , Portugal
J. Starke, Lyngby , Denmark
N. Strömberg, Jönköping , Sweden
A. Tereso, Guimarães , Portugal
A.M. Toader, Lisbon , Portugal
D. Tortorelli, Urbana-Champaign , United States
I. Tsalicoglou , Zurich , Switzerland
J. Vasconcellos, Rio de Janeiro , Brazil
M. E. Vazquez-Mendez, Santiago de Compostela , Spain
M.M.B.R. Vellasco , Rio de janeiro , Brazil
A. Vidard, Grenoble , France
N. Volpi, Curitiba , Brazil
V. Vondrak, Ostrava-poruba , Czech Republic
D. Vucinic, Brussels , Belgium
M. Y. Wang, Shatin , Hong Kong
L. Wrobel, Uxbridge , United Kingdon
S. Yang, Taipei , Taiwan
V. Yepes, Valencia , Spain

Table of Contents

** presenting authors*

Bio-inspired and Heuristic Optimization 14

Civil Engineering 20

Composite Material Optimization – Smart Structures 23

Inverse Problems and Parameters Estimation. 47

Mathematical Optimization Techniques 52

Mechanical Engineering – Manufacturing – Machinery. 56

Oil and Gas Applications 61

Structural Optimization. 87

System Control and Dynamic Optimization 102

Topology Optimization 105

Introduction

EngOpt 2012 is the third edition of a series of well succeed international meetings on Engineering Optimization. The main goal of EngOpt conferences is to periodically bring together engineers, applied mathematicians and computer scientists working on research, development and practical application of optimization methods applied to all engineering disciplines or developing basic techniques in this field..

ENGINEERING DESIGN OPTIMIZATION

Modern design techniques seek for the best design to perform the desired tasks. Engineering Optimization deals with the optimal design of elements and systems in all engineering fields.

Nowadays, use of Design Optimization techniques is rapidly growing in most of engineering disciplines, like automotive, aeronautical, mechanical, civil, nuclear, naval, mechanical, electrical, energy and off-shore engineering. This is due to the increase of technological competition and the development of strong and efficient techniques for several practical applications.

MDO - MULTIDISCIPLINARY DESIGN OPTIMIZATION

Engineering Systems are increasingly complex and represented by large and sophisticated numerical models. They involve several interacting disciplines or are made up of distinct interacting subsystems that must be considered simultaneously to obtain efficient designs.

Multidisciplinary Design Optimization is devoted to the design of complex systems involving interacting subsystems or disciplines. The main scientific challenges of MDO are concerned with the development of strong and efficient numerical techniques and with the computational organization required for the necessary coupling of codes employed in interacting disciplines.

INVERSE PROBLEMS

Numerical methods for inverse problems in most of cases are based on optimization techniques similar to those employed in optimal design. This field, applied in all engineering disciplines, is of utmost importance for Engopt conference.

ENGINEERING SIMULATION INVOLVING OPTIMIZATION TECHNIQUES

Several physical phenomena are naturally represented by an optimization problem. This is the case when the "equilibrium" is attained at the minimum of an energy function. In several applications, constraints must be satisfied. This is the case of contact problems is solids mechanics.

BASIC NUMERICAL TECHNIQUES

Engineering Optimization requires a large set of basic computer tools. This is the case of several CAD tools for geometric modeling, engineering analysis methods, sensitivity analysis as well as mathematical programming and genetic or evolutionary optimization algorithms.

ABOUT INTERDISCIPLINARITY IN ENGINEERING OPTIMIZATION

Modern Engineering Optimization is strongly interdisciplinary in two axes. The need of integration of basic and applied techniques and to solve real engineering problems, requires the cooperation of engineers, mathematicians and computer scientists, working on research and practical application.

A fundamental need for MDO is also the establishment of a strong communication of scientists and practitioners acting in different Engineering Disciplines.

EngOpt is intended to be a forum to expose and share current and future research and innovation in all techniques involved in Engineering Optimization as well as in the relationships among them.

Aerodynamics

UNSTEADY AERODYNAMIC DESIGN OPTIMISATION OF MULTI-ELEMENT HIGH LIFT SYSTEM USING ADVANCED MOGA

ESPINOZA, Hector* *International Center for Numerical Methods in Engineering (CIMNE)/UPC, Spain*
LEE, DongSeop *Deloitte Analytics & CIMNE, Korea*
CODINA, Ramon *CIMNE/UPC, Spain*
PERIAUX, Jacques *CIMNE/UPC, Spain*

Design of multi-element High Lift Systems (HLS) for unmanned/civil aircraft has become ever-increasingly important and the topic remains in the forefront of aerospace research. Since small improvement in the aerodynamic performance of the high lift system can reflect to a large increment of payload during take-off and landing. This paper investigates the High Lift System (HLS) application of complex aerodynamic design problem using Multi-Objective Genetic Algorithms (MOGAs) coupled to unsteady Computational Fluid Dynamics (CFD) analyser. Multi-element High Lift Systems consists of slat, main and flap aerofoils. For MOGAs, distributed/parallel MOGA developed at CIMNE is used. CFD analyser uses a sub-grid scale method as an alternative to the more classical DNS or LES for the numerical simulation. In this paper, the unsteady CFD analyser is validated by comparing with wind tunnel data. Unsteady CFD analyser coupled to MOGA is implemented to find the best combination of multi-element high lift systems to produce higher lift to drag ratio (L/D) and lift coefficient (Cl) at take-off and landing conditions respectively. Numerical results obtained from the multi-objective HLS design optimisation show that designing multi-element aerofoil positions using MOGA coupled with unsteady CFD analyser improves the aerodynamic efficiency of HLS at both take-off and landing conditions. Results also indicate that the method is efficient and produces a set of useful non-dominated optimal solutions.

AERODYNAMIC SHAPE OPTIMISATION USING FIRST AND SECOND ORDER ADJOINT GRADIENTS, COUPLED WITH CAD SENSITIVITIES

CHRISTAKOPOULOS, Faidon* *Queen Mary, University of London, United Kingdom*
MÜLLER, Jens-Dominik *Queen Mary, University of London, United Kingdom*

Numerical optimisation for fluid flow is an essential design tool to fulfil demanding requirements for performance and environmental impact. It can replace the traditional technique of design improvement via trial and error. Adjoint methods , as a part of numerical optimisation methods, are essential for industrial CFD design optimisation as their cost is independent of the number of design variables. In the present paper, an advanced methodology of developing a novel fully turbulent compressible adjoint solver through Automatic Differentiation is presented and issues of code automation and maintenance are addressed. Furthermore, the computation of second order sensitivity information via adjoint is discussed and a novel method for convergence acceleration is proposed. Moreover, a gradient-based optimisation algorithms using first and second derivatives is coupled with Computer Aided Design (CAD) sensitivities . The arising challenges are discussed in depth and the mathematical and physical background is detailed. The developed methodology is applied to industrial testcases and results are presented confirming the efficiency and validity of the proposed methodology.

AERODYNAMICAL GLOBAL SHAPE OPTIMIZATION AT TWO SUPERSONIC CRUISING MACH NUMBERS, BY MORPHING

NASTASE, Adriana* *Aachen University, Germany*

Let us consider a flying configuration (FC), which is flying at two different cruising supersonic Mach numbers over sea and land. The aerodynamical global optimized (GO) shape of a FC can be realised by morphing. Leading edge flaps, movable in spanwise direction, are used for this purpose. The surfaces of the wing, of the fuselage and of the flaps of FC in open position are approximated in form of different superpositions of homogeneous polynomes in two variables. The coefficients of these polynomes and the similarity parameters of the planforms of the FC, flying with movable leading edge flaps in retracted and, respectively, in open position, are the parameters of optimization. Two enlarged variational problems with free boundaries occur. The first one concerns the determination of the GO shape of the wing-fuselage FC, which is flying at higher cruising Mach number with the flaps embedded inside the wing thickness. The second one concerns the determination of the GO shape of the flaps at the lower cruising Mach number. The iterative optimum-optimorum theory of the author is used as strategy for the solving of both enlarged variational problems and new proposed hybrid analytical-numerical solutions for the Navier-Stokes PDEs are used as start solutions for the GO shapes of FC with flaps in open and, respectively, in retracted position.

AN INTERIOR POINT GRADIENT-BASED OPTIMIZER FOR AIRCRAFT DESIGN

QUANG, Dinh* *Dassault Aviation, France*
RAVACHOL, Michel *Dassault Aviation, France*
ROGÉ, Gilbert *Dassault Aviation, France*
HERSKOVITS, José *Coppe/Federal University of Rio de Janeiro, Brazil*

Since the mid-1990's, Dassault Aviation (DA) has developed, for its aircraft (AC) design work, an optimization software following seminal algorithmic ideas of the 4th author (JH), as detailed in refs [1] & [2]: a deterministic gradient-based quasi-Newton Interior-Point algorithm. In what follows, this optimizer will be called FIPA, for Feasible Interior Point Algorithm. Starting in June 2010, DA has been involved in a collaborative work with JH to improve FIPA, adding new interesting numerical features, ref[3]. In this paper, we shall show how DA is using FIPA for AC design, the improvements of FIPA, as planned in our on-going collaboration and the future directions, as can be inferred from our needs. There are 2 main fields where FIPA is used: aerodynamic optimization using large-scale simulations and preliminary AC design. Aerodynamic optimization is the field where FIPA was initially introduced in DA. We are dealing here with mainly shape optimization using large scale Computational Fluid Dynamics (CFD) simulations. A relatively small number of design parameters (10 to100) is driving the mathematical programming problem with a comparable number of functions, objective and constraints. However, the evaluation of functions is very costly, as it requires CFD simulations using High Performance Computing with large-scale meshes (millons of nodes). Gradients of functions, w.r.t. the design parameters, are computed using the adjoint approach, allowing us to eliminate the huge number of (CFD-) field equations, which otherwise must be included as equality constraints in the initial mathematical programming model. Preliminary AC design has quite distinct features: - Multi-disciplinary context: the disciplines (aerodynamics, structures, acoustics etc.) interact through reduced models. - Gradients are not available: their evaluation is usually done via Finite Differences (FD) techniques. - Relatively fast evaluations of functions which are "noisy". [1] An Interior Point Technique for Non-linear Optimization, J. Herskovits - Research report 1808, INRIA, Le Chesnay, France, 1992. [2] On the computer implementation of Feasible Direction Interior Point algorithms for Non-linear Optimization, J. Herskovits, G. Santos - Structural Optimization, 14, pp. 165-172, (1997). [3] Feasible Arc Interior Point algorithms for Non-linear Optimization, J. Herskovits, G. Santos - Computational Mechanics: New trends and Applications, CIMNE, Spain, 1998.

ROBUST AND RELIABILITY BASED DESIGN OPTIMIZATION FRAMEWORK FOR WING DESIGN

SULEMAN, Afzal* *Instituto Superior Tecnico, Portugal*
CRAWFORD, Curran *University of Victoria, Canada*
PAIVA, Ricardo *University of Victoria, Canada*

This paper outlines an architecture for simultaneous analysis and robustness and reliability calculations in aircraft design optimization. Robust Design Optimization and Reliability Based Design Optimization are unified in a formulation which streamlines the setup of optimization problems and aims at preventing foreseeable implementation issues in uncertainty based design. To avoid extensive computational time that would be the result of a direct evaluation approach to nondeterministic optimization, surrogate models are employed. Robustness and reliability based optimization is tested both in simple analytic problems and more complex wing design problems revealing that performance benefits can still be achieved while obeying precise probabilistic constraints rather than the simpler (and not as computationally intensive) robust constraints. The latter are proved to be unable to follow a prescribed reliability constraint as uncertainty in the input variables increases. The computational effort of reliability analysis is further reduced through the implementation of a coordinate change in the respective optimization subproblem to solve for the distance from the current iterate to the most probable point of failure.

Aeronautics

SIMULTANEOUS AEROSTRUCTURAL OPTIMIZATION OF AN AIRCRAFT WING PLANFORM AND INTERNAL STIFFENER CONFIGURATION SUBJECT TO AEROELASTIC CONSTRAINT

SEOW, Vincent Y. E.* *University of Bath, United Kingdom*
LU, Kai *University of Bath, United Kingdom*
KIM, H. Alicia *University of Bath, United Kingdom*

The concept of Multidisciplinary Design and Optimization (MDO) has been a subject of interest in the aerospace industry over the past several decades. One common MDO application is in the aircraft wing design where the tradeoff between aerodynamic and structural efficiency is a major consideration. This coupling effect adds complexity in high fidelity aerostructural analysis and optimization. This paper presents a multidisciplinary optimization of a wing subject to constraints on structural strength and aeroelastic stability. An optimization procedure is developed to optimize the wing planform and the internal stiffener configuration simultaneously. In the wing planform optimization, the objective function is to minimize induced drag by determining the optimum set of geometrical variables such as span, taper ratio, twist angle and sweep angle. The doublet lattice method is employed for sensitivity analysis and sequential quadratic programming is used to find the optimum wing planform. This is then coupled with the internal layout optimization for the wing structure via level set topology optimization. The volume of the structure and the flutter stability are imposed on topology optimization as constraints. The structure is modeled as a 2D flat wing using Mindlin plates. The popular front-tracking algorithm is employed for level set topology optimization. As topology is updated, stiffness of the wing changes which in turn, changes the aerodynamic load distribution. This aerostructural interaction is considered throughout the coupled optimization procedure thus obtaining the optimum wing structure for the optimum aerodynamics loading. The numerical results of optimum wing structures under a subsonic condition will be presented and a feasibility of the method for composite structures will be discussed.

MULTIPHYSICS OPTIMIZATION OF THE PIEZOELECTRIC FLAPPING WING PROPULSION

BIDAKHVIDI, M. Ahmadi *Vrije Universiteit Brussel, Belgium*
VUCINIC, Dean* *Vrije Universiteit Brussel, Belgium*
VANLANDUIT, Steve *Vrije Universiteit Brussel, Belgium*

Flexible plates with a piezoelectric patch can be used, as energy harvesting devices and actuating mechanisms, for the cooling devices or the MAV wing propulsion. The complex motion, of such oscillating plates, is defined by the actuation frequency and the mode shapes. The structural optimization of the plate tip deflection, in terms of the maximum efficiency, does not necessarily match the aerodynamic optimization of the oscillating wing induced flow, due to the coupled fluid structure interaction phenomena. In this study, we investigated the multiphysics problem of the piezoelectric flapping wings propulsion, recognizing that the related optimization criteria is very application dependent and thus, based on the parameters: mode shape, flapping frequency, tip deflection, maximal electromechanical coupling factor (EMCF) and aerodynamic condition. In this paper, we give contribution to this challenging optimization problem, by presenting the applied models and by analyzing the obtained results, which are discussed in detail, together with the best practices learned.

ADAPTIVE WAVEFORM DESIGN BASED ON MULTI-OBJECTIVE OPTIMIZATION FOR OFDM-STAP RADAR

SEN, Satyabrata* *Oak Ridge National Laboratory, United States of America*
GLOVER, Charles W. *Oak Ridge National Laboratory, United States of America*

We propose a Pareto-optimal waveform design approach for an orthogonal frequency division multiplexing (OFDM) radar signal to detect a target using the space-time adaptive processing (STAP) technique. The frequency diversity of the OFDM signals provides us with additional information about the target, as different scattering centers resonate at different frequencies, and thus improves the target-detectability in the presence of background clutter and hostile jamming. Moreover, the use of an OFDM signal enables us to adaptively design its spectral parameters in order to further improve the system performance. First, we develop a parametric OFDM-STAP measurement model by considering the effects of signal-dependent clutter and colored noise, and then show that the expression of the optimal OFDM-STAP filter weights is similar to that of a conventional STAP filter. Next, we observe that the resulting STAP-performance can be improved by maximizing the output signal-to-interference-plus-noise ratio (SINR) with respect to the OFDM spectral parameters. However, in practical scenarios, the computation of output SINR depends on the estimated values of the target spatial and temporal (Doppler) frequencies, target scattering coefficients, and interference-plus-noise covariance matrix. Hence, obtaining good estimates of these quantities is as equally important as improving the output SINR. We know that the Cramer-Rao bound (CRB) is a universal lower bound on the variance of all unbiased estimators of a set of parameters. Therefore, in addition to maximizing the output SINR, we minimize the CRB on the normalized Doppler frequency, calculated for the known spatial frequency, target response, and interference-plus-noise covariance. So, overall we formulate a constrained multi-objective optimization (MOO) problem to design the spectral parameters of the OFDM waveform by simultaneously optimizing two objective functions: maximizing the output SINR to increase the STAP-performance, and minimizing the CRB on the normalized Doppler frequency estimation in order to improve the efficiency of the underlying estimation problem. Instead of using the scalarization technique to solve the MOO problem, we apply the well-known nondominated sorting genetic algorithm II (NSGA-II), which belongs to the class of evolutionary algorithms. We present several numerical examples to demonstrate the performance improvement due to the adaptive waveform design.

AN MDO FRAMEWORK FOR TOPOLOGY OPTIMIZATION OF AIRCRAFT STRUCTURES

FELIX, Luis *Academia da Forca Aerea, Portugal*
GOMES, Alexandra Aguiar *Instituto Superior Tecnico, Portugal*
SULEMAN, Afzal* *Instituto Superior Tecnico, Portugal*

A multidisciplinary analysis and optimization framework for aircraft's wing design is presented. This framework is organized in independent modules to facilitate future updates. Not only it includes a wing model input and optimization setup module, but also includes aerodynamics, structural, aeroelastic and cost analysis modules. The different modules can either be used as individual analysis tools or coupled in an optimization problem. A new module dedicated to topology optimization is being implemented which is the main topic of this paper. The current version of the MDO tool solves an FSI optimization problem where the wing structure is defined with spars, ribs, stringers and skin. With the aim of increasing the range of possible designs, topology optimization is implemented as a new module in this tool in order to allow for new structural configurations to be considered. In this paper we address the problem of minimizing a structure compliance for a given volume, which is solved with the approach of Solid Isotropic Material with Penalization (SIMP). An in-house code with 2D and 3D element is used to solve the finite element problem. We present some simple 2D and 3D problems of a cantilever beam that were used to compare the performance of different optimization algorithms (CFSQP and GCMMA) when applied to topology optimization. Despite having a good performance when used to solve the FSI optimization problem, the algorithm CFSQP was unable to deal with the several design variables inherent to the SIMP approach. These case studies were also used to compare the mesh-independent filter with morphological based density filters. While the first one is simpler to implement, morphological based filters are computational more efficient and the solution has less gray elements. These case studies also demonstrate that the resultant structure shape is filter dependent. The topology optimization tool has been used in the MDO framework to optimize the shape of wing spar. It was possible to reduce the 40% of the spar volume without significant increase in compliance for the same wing load. In order to find new structural layouts, the topology tool has been implemented to optimize the

internal distribution of material of a block with the outer shape of a wing. Given the same aerodynamic load, the problem is solved for different volume reductions and different definitions of the wing surface, which is not included in the set of design variables.

BALANCED APPROACH IN AIRPORT NOISE CONTROL: A MULTIDISCIPLINARY OPTIMIZATION PROBLEM

SLAMA, Jules Ghislain* *COPPE, Federal University of Rio de Janeiro, Brazil*
GAMA, Ana Paula *COPPE, Federal University of Rio de Janeiro, Brazil*

In environmental acoustics the issue of urban noise control is multidisciplinary. We consider four different aspects, the propagation medium, the sources and fields generated, land use and the dose-response relationship of populations. From these trends a policy of noise control can be established. Urban noise limits appears as restrictions and the optimization function can be the cost or time. In the case of airport noise, ICAO (International Civil Aviation Organization) has presented In the Resolution A33 / 7, 2001, the balanced approach which is related the problem of airport noise control. In this approach the four aspects considered are: Reduction at source of aircraft noise, planning and land management, operational procedures for reducing noise, operational restrictions. The one that presents more difficulties in implementation is management of land use in the case of Brazil. The urban zoning aims to ensure the comfort of the population, divide the city into zones and for each zone set a noise criterion level as a restriction at daytime and a nighttime test. The metric used is the equivalent sound level. The Airport zoning aims to limit the noise annoyance in the community and defines an airport zoning which consists in concentric areas at constant noise metric values .The metric used for the zoning is DNL which is 24h metrics and is directly related with annoyance. This paper discusses some aspects of the balanced approach as a multidisciplinary optimization problem and particularly the planning and land management.

NAVIGATION SOLUTION ERRORS REDUCTION THROUGH INERTIAL SENSORS DATA FUSION IN A REDUNDANT BI-DIMENSIONAL STRAP-DOWN INERTIAL NAVIGATOR

GRIGORIE, Teodor Lucian* *University of Craiova, Romania*
BOTEZ, Ruxandra Mihaela *Ecole de Technologie Superieure, Canada*
SANDU, Dragos George *In Flight Research and Test Center, Romania*

The paper presents a redundant architecture of a bi-dimensional strap-down inertial navigator in horizontal plane. The redundance of the developed system is provided by its inertial measurement unit, containing inertial sensors arrays in a linear redundant configuration. The inertial sensors data in each of the three arrays (two for accelerometers, along the reference axes in horizontal plane, and another one for gyros, along the vertical axis) are fused by using a statistical method derived from the maximal ratio combining method. Shown are: the navigator inertial measurement unit structure, the fusion algorithm theory, the inertial navigator theory of operation, and the experimental validation of the proposed architecture. In the experimental validation phase the positioning, speed and attitude errors are evaluated and discussed relative to the reference signals provided by a SDINS/GPS integrated navigator.

DETERMINATION OF LIGHTING COMFORT IN AN AIRCRAFT CABIN

VERTAMATTI, Egidio* *USP - POLI Escola Politécnica de São Paulo, Brazil*

One of the conditions for airlines to stay in the passenger transport market, it is offer to its passengers service and infrastructure with comfort and quality, in order to satisfy and to conquer its passengers. One factor that contributes to the discomfort of the passenger is the quality of light, either directly (for reading) or indirectly (environment light). Some factors that cause the lighting discomfort are: color of light, color of objects, contrast, brightness, luminous intensity, color temperature of light, reflection and texture of objects. The objective of this research is to find ways to determine the discomfort caused by lighting in the cabin of an aircraft, evaluating and quantifying the influence of parameters of objects (color, texture, brightness) and light (color temperature, spectral distribution and space of light, color, intensity), taking in account that the discomfort is dependent on exposure time in a given environment. A statistical study was done through a questionnaire which will assess the sensations that a specific condition of lighting produces in the individuals. The research environment will be a replica of an aircraft cabin. The results to be obtained in this

study of discomfort caused by lighting could be helpful to people making a decision to travel, knowing that they will be in a comfortable environment. The airlines that offer this differential may have advantages in the preference of passengers. Besides the practical possibilities of application in aircraft cabins, the proposed research may extend to other cases, improving the comfort in any environment where the adequate lighting is welfare synonymous

Automotive Industry

SHAPE BLENDING OPTIMISATION FRAMEWORK FOR SHELL STRUCTURES

DU CAUZE DE NAZELLE, Paul* *RENAULT – Ecole Centrale de Lyon, France*
FOURCADE, Christian *RENAULT, France*
GILLOT, Frédéric *Ecole Centrale de Lyon, France*
TOURBIER, Yves *RENAULT, France*
JEZEQUEL, Louis *Ecole Centrale de Lyon, France*

Sheet-metal mechanical structures are commonly used in the industry and especially for automotive design. Performances of such structures regarding various mechanical criteria are closely linked to their shapes (stiffener, curvature...). Shape optimization of such structures have widely been studied, topography and morphing methods are nowadays commonly used to solve shape optimization problems. Unfortunately, both of these methods based on mesh deformation, may imply mesh quality difficulties or additional and timeconsuming steps for re-meshing. Other CAD-based approaches can also provide efficient results but sticks around an original design imposed by the initial construction of the CAD model. Moreover, CAD-based optimization hardly proposes solutions with topology changes. In this paper, we propose an innovative optimization framework based on the intrinsic description of the shape in the thin shell equations. Indeed thin shell theory represents the shape as a transformation function between a 2D domain and a 3D shape. Thus, mechanical equations intrinsically describe the shape and are solved on the fixed 2D domain. We propose to use this transformation function as parameters for optimisation. We define a set of elementary functions, each describes an elementary shape. Complex surface can hence be described as a linear combination of elementary shapes. The size of the optimisation problem is then controlled by the number of elementary shapes involved in the global optimal shape to reach, as well as each elementary shape transformation function parameters. We apply our proposed framework for the optimal design of an engine hood substructure with regard to its mass and vibration response. In order to show the efficiency and accuracy of our approach, we compare our results to those from a classical parametric approach from an initial CAD design and a topological approach.

ON THE USE OF EMPIRICAL LIKELIHOOD-BASED SPREAD REGRESSION IN THE CASE OF FLYWHEEL ASSEMBLY

GADEK-MOSZCZAK, Aneta* *Cracow University of Technology, Poland*
PIETRASZEK, Jacek *Cracow University of Technology, Poland*

This paper proposes combining the spread regression and the empirical likelihood (EL) as the consistent approach to the automotive industry optimization problem. The investigated object was a flywheel, whose elements were tightened during assembly with the eight screws driven to the cast iron body. The tightening was carried out with a multiple-spindle machine in a complex scheme of sequences. Originally, the flywheel was mounted using screws with washers. A drastic form of an economic adjustment, induced by the economic crisis, imposed the cost reduction manifested, among others, in the removal of steel screw washers. This led to an instability of the process of tightening the steel screws into cast iron body: torque values were very often located far beyond the allowable range. Management decided to implement the recovery program including improvements based on the experimental design methodology. The obtained data were modeled by the spread regression coupling means approximation with confidence intervals based on the empirical

likelihood. Such an approach appeared to be the convenient tool for modeling the mean and confidence interval limits in one consistent procedure. The spread regression was first used by Tanaka in 1982 for fuzzy (possibilistic) regression as an approach minimizing the fuzziness of the assumed model. In the next years, this approach has been used in various modifications. The empirical likelihood was first proposed by Owen in 1989 and rapidly developed in the next years. Unlike in the classical approach assuming the normal distribution of data, the EL-based confidence intervals are significantly narrower in the case of small samples. Additionally, the empirical likelihood approach is data-driven with no assumption of a specific distribution of data and it may be classified as the non-parametric method. The paper contains: problem definition, presentation of the measured data and the final analysis with comparison to the alternative approach: the classical regression based on DoE. The benefits of the proposed approach are shown in the case of small size samples. The empirical likelihood and the spread regression calculations were processed in PTC Mathcad numerical software. The experimental design calculations were processed using Minitab software.

EFFICIENT OPTIMISATION OF THE STRUCTURE OF A PASSENGER BUS BY ITERATIVE FINITE ELEMENT MODELS WITH INCREASING DEGREES OF COMPLEXITY

RUÍZ, Osvaldo* *Universidad Nacional Autónoma de México, Mexico*
RAMÍREZ, Edgar I. *Universidad Nacional Autónoma de México, Mexico*
JACOBO, Víctor. H. *Universidad Nacional Autónoma de México, Mexico*
SCHOUWENAARS, Rafael *Universidad Nacional Autónoma de México, Mexico*
ORTIZ, Armando *Universidad Nacional Autónoma de México, Mexico*

The optimisation of the mechanical response of automotive chassis and body designs increasingly relies on advanced finite element models. In the international market for passenger cars, the design process can rely on centralised supercomputing facilities. For passenger buses, there are still many "local" producers, which construct vehicles based on local needs. To stay competitive, these producers must comply with the same requirements reliability and weight reduction as their international counterparts, even without access to advanced computation facilities. This work describes an iterative optimisation in which the sophistication of the finite element models was adapted to the degree of refinement required in each of the iterations. The starting structure was designed based on previous experience. This design was analysed by a wireframe model using beam elements, which could be efficiently calculated on a conventional workstation. The first iteration consisted in identifying the structural elements subject to low loads in the original design. In the corresponding zones, structural elements were either removed or their section was modified in shape and size to bring the local loads into closer agreement with the average load observed in the model. This reduced the weight of the structure with 8% without affecting the stiffness or strength. After this step, critical zones were modelled by full 3D meshes to avoid overlooking local stress concentrations in the junctions between heavily loaded structural elements. This was followed by the implementation of the vehicle suspension into the FEM-model and finally a full 3D-meshing of the entire structure. The final model had to be run only once, and even then, it took only 48 hours of calculation on a state-of-the-art workstation. It confirmed that all the previous models were sufficiently accurate. However, as these had to be run many times in the adaptive optimization process, their efficiency allowed for quick corrections in each subsequent optimisation step. As a result, significant weight reduction was achieved, non-essential components were removed and the design time was significantly reduced.

MODEL PREDICTIVE CONTROL FOR VEHICLE YAW STABILITY

CHOI, Mooryong* *KAIST, Korea*
CHOI, Seibum *KAIST, Korea*

Yaw stability of an automotive vehicle in a turn is critical to the overall stability of the vehicle. In this paper, we present a method of vehicle stability control (VSC) based on Model Predictive Control (MPC). Conventional VSCs work passively as they detect excessive yaw rate or slip angle of a vehicle. However, in many cases, when excessive yaw rate or slip angle of a vehicle is detected, the vehicle is already in unstable situation. Using the MPC scheme, the proposed controller can actuate brakes to generate correction moment in advance of vehicle being unstable by predicting vehicle movement of several hundred milliseconds ahead. The differences of desired vehicle states from the bicycle model and the estimated vehicle state are minimized by applying the MPC scheme. The performance of the proposed method is evaluated using the vehicle dynamics software CARSIM.

TOOTHED CONTINUOUSLY VARIABLE TRANSMISSION (CVT) FOR TRANSPORT

IVANOV, Konstantin Samson* *Almaty University of Power Engineering and Telecommunications, Kazakhstan*

Abstract. The developed toothed continuously variable transmission (CVT) in the form closed gear differential is reliable mechanical system which provides high load ability and reliability. Laws of mechanics allow creating the mechanical transmission, capable to bring a transfer ratio into accord to loading only due to properties of the mechanism without use of any control. The gear differential with two degrees of freedom contains a closed contour of toothed wheels which imposes additional differential constraint on motion of links and converts a kinematic chain into the mechanism. Thus the mechanism acquires property of adaptation to variable external loading. It allows using this transmission for lorry which works in the intense force conditions. The account of transmission includes the correct selection of tooth wheels numbers and use of inertial properties of transmission at start up. Besides, the mechanical transmission with two degrees of freedom can change output shaft rotation if a stopping of one of wheels for simple creation of a back trailing of the car. Keywords: toothed transmission, reliability, closed contour, adaptation.

BUS SUSPENSION MODELING AND ANALYSIS BY FINITE ELEMENT SOFTWARE

REYES, Carlos *UNAM, Mexico*
RAMÍREZ, Edgar I.* *UNAM, Mexico*
RUÍZ, Osvaldo *UNAM, Mexico*
SCHOUWENAARS, Rafael *UNAM, Mexico*
ORTIZ, Armando *UNAM, Mexico*

The main objective of this paper is to obtain loads and moments at the fixing points for commercial bus suspensions using finite element software, under different study conditions. Structural analysis requires determination of loads under which is working, for this particular case, those transmitted by suspension under different operational conditions, such that modeling of their mobile mechanisms is useful. Starting from the dynamic automotive equations, associated loads to each of the bus three axles are determinate, such loads assume a bus in maximum load condition. The evaluated conditions in order to obtain axle forces are: suspended weight, which is a static bus at maximum load; acceleration and breaking, from where can be obtained the load transference between frontal and rear axles; cornering, which represents the load transfer from one side of the bus to the other; cornering and breaking, this implies superposition of two conditions mentioned before. Geometry of the different pieces was obtained directly from the CAD files for each commercial suspension axle, likewise freedom degrees were identified, either between to piece-piece movement as well as piece-bus body elements. From loads obtained with analytical equations, values to be applied to each tire were determinate. Modeling of pieces was developed considering wire elements, to which mechanical properties of steel and different cross-sections were assigned. Additionally connectors were used in order to modeling of dynamic components such as air springs, shock absorbers and tires, to which were assigned characteristic curves behavior. The fasteners most critical were found to be air springs, above which cuasi-static analysis developed carries an elevated percentage of load, meanwhile for curving conditions torsion arms become critical analysis elements. From models were obtained reactions at all fasteners of suspension with the bus, thus has input information for a future design of suspension brackets.

AUTOMOTIVE VEHICLE LAUNCH OPTIMIZATION BASED ON DIFFERENTIAL EVOLUTION (DE) APPROACH FOR INCREASED DRIVEABILITY

BACHINGER, Markus *Virtual Vehicle, Austria*
KNAUDER, Bernhard* *Virtual Vehicle, Austria*
STOLZ, Michael *AVL List GmbH, Austria*

An important target for automated transmission development is driveability during the launch process of a vehicle. For transmissions using launch clutches the friction energy has to be considered to avoid thermal breakdown. The launch process is controlled by electronic control units containing functions tunable by parameters. Optimizing those parameters can be time-consuming when testing on a real vehicle. Using simulation on a surrogate model as input for evaluation of the cost function can lead to significant cost savings as well as shorter development time in automotive applications. In this work we contribute a lean mathematical model of a vehicle's drivetrain tailored for optimization of the launch process. The model includes combustion engine, inertias, clutches, flexible shafts and control algorithms for engine and clutches. The two design parameters clutch closing time and scaling factor for clutch slip speed are chosen to optimize

the cost function taking into account driveability and clutch friction energy. As the cost function is nonlinear and not even continuous, we propose using a DE approach, which does not require the knowledge of the cost function's gradient. To further speed up optimization a surrogate cost function is built using a radial basis function approach. Found optimal parameters for clutch closing time and scaling factor for clutch slip speed shall be applied to a prototype vehicle as initial parameterization. The full manuscript will show a realistic launch simulation with optimized parameters and will work out the suitability of a DE approach for the given task.

Bio-inspired and Heuristic Optimization

HEURISTICS FOR THE CLOSEST STRING PROBLEM

LYRA, Adria *UFRRJ, Brazil*

Lots of problems in Molecular Biology seek to compare and find common regions to a set of DNA, RNA or proteins sequences. These problems have lots of applications, such as search specific patterns in sequences, identifications of genetic drugs, formulation of genetic probes, among others. In this work, we deal with the Closest String Problem (CSP). The CSP is a NP-hard problem that aims at finding the closest string of a given set S of sequences, according to a predefined metric. We define the the CSP as a set S = {s_1, s_2, ..., s_m} of sequences of size n over an alphabet \Sun. The objective is to find a sequence s_H of size n that minimizes the distance between s_h and s_i, for all i in {1, 2, ..., m}. Here we implement and analyze three construction heuristics, one local search and one path relinking. One of these construction heuristics is a 2-approximative method from the literature. We also propose two other construction methods, one deterministic and the other non-deterministic. The best results are the obtained by the non-deterministic construction heuristic proposed in this work, so we can assure that our results are at least 50% from the optimum solution.

INVESTIGATING THE EFFICIENCY OF THE SURROGATES BASED ON NEURAL NETWORKS IN ASSISTING MULTI-OBJECTIVE OPTIMIZATION OF TEST-PROBLEMS PERFORMED BY A NON-GENERATIONAL GENETIC ALGORITHM

BARBOSA, Alexandre Nogueira* *Instituto de Aeronáutica e Espaço, Brazil*
GUIMARÃES, Lamartine Nogueira Frutuoso *Instituto de Estudos Avançados, Brazil*

The design of non-guided suborbital rockets requires simulations to evaluate the stability of the rocket as function of the shape of its fins. The search for the best fin is a trial and error process, whose conflicting objectives are the stability and the rocket performance. Benefiting the stability from increasing the shape of the fin causes excess drag, which affects the performance. A study to do the multi-objective optimization of the fin motivates this subjacent investigation. A single simulation involves interactions between aerodynamics and trajectory calculations, which can take more than 10 seconds in a 3 GHz dual-core. As a result, the optimization becomes time-consuming since it requires hundreds of simulation evaluations. The approach is the Surrogate-assisted Design Optimization. This paper is concerned with the surrogates based on neural networks. The Multilayer Perceptron and the Radial Basis Function network have been employed for constructing surrogates in engineering design optimization. The original contribution of this work is a way to assess the efficiency of these surrogates in terms of the simulation evaluations, considering the characteristics of the optimization technique. Since the gradient of the objective function, which evaluates the fin shape, is difficult to obtain, an evolutionary optimization based on a non-generational genetic algorithm is employed. The non-generational approach is adequate for a multi-objective problem because preserves individuals in the population that are closer to the Pareto front. In order to investigate the efficiency of the surrogates, some test-problems available in the literature are considered. For each test-problem, this paper proceeds as follows. First, different attempts of each surrogate are selected and assessed. The attempt with the smallest generalization error is chosen. The Latin Hypercube sampling is employed to generate the initial dataset for surrogate estimation, validation and test. Then the surrogate-assisted optimization follows a search and update procedure. New samples found by the genetic algorithm and tested by the original model are added to the dataset. The steps of surrogate construction, genetic algorithm search and dataset update repeat until the Pareto front approximation is enough. Finally, the surrogate efficiency is assessed. This paper ends with a comparison of the surrogates in terms of efficiency and further application in the rocket fin optimization.

PARTICLE SWARM OPTIMIZATION METHOD WITH NEW VELOCITY UPDATE SCHEME

MONTEIRO, Bruno da Fonseca* *Universidade Federal do Rio de Janreiro, Brazil*
LIMA JR, Mauro Henrique Alves de *Universidade Federal do Rio de Janeiro, Brazil*
ALBRECHT, Carl Horst *Universidade Federal do Rio de Janeiro, Brazil*
JACOB, Breno Pinheiro *Universidade Federal do Rio de Janeiro, Brazil*

The bio-inspired optimization techniques have obtained great attention in recent years due to its robustness, simplicity and efficiency to solve complex optimization problems. The Particle Swarm Optimization (PSO) algorithm is an optimization method with these great features. This work proposes a new strategy to improve the PSO. It provides a new way to evolve the method by updating the velocity, position and fitness value of a single particle, and checking whether this particle is a new global best. Then, it moves on to the next particle in the same generation. So, several particles can be updated using various global best in a same generation, that is, this method may have many evolutions in the same generation. Benchmark functions are analyzed by comparing the classical PSO with this new one. The obtained results show that the proposed strategy has a better performance.

A PERFORMANCE-BASED GENERATIVE DESIGN APPROACH USING MULTI-OBJECTIVE OPTIMIZATION IN ARCHITECTURAL DESIGN

NICKNAM, Mahsa* *Illinois Institute of Technology, United States of America*
ELNIMEIRI, Mahjoub *Illinois Institute of Technology, United States of America*

This research paper aims to incorporate multidiscipline performances like structure and energy into the architectural form generation process. To this end, it proposes a generative design approach using Genetic Algorithm for the exploration of form based on performance criteria which leads us to a new integrated design approach in architecture. In the current practice, issues pertaining to building performance such as structure and energy conservation considerations are typically dealt with after the architectural form is well articulated. Such approach may enable a building to stand upright, and may also reduce the energy consumption in the building. But there will be no guaranty that it will produce optimum structure or energy efficient solutions. Therefore, this research paper seeks to emphasize the integration of different disciplines into the design process by providing the numeric evaluations and performance simulations in the form generation process. Hence, a performance-based generative design approach is proposed in this research work based on genetic algorithm and building simulation softwares. This method uses parametric modelling to generate the form for its possible variations and Genetic Algorithms as an optimization algorithm to explore the link between form and performances. From a schematic design and a set of rules and constraints that encode the architect's criteria and intentions, the proposed approach searches the solution space for the architectural design configurations that satisfied the predefined objectives. Hence, in this approach, design is considered as a process of a repeated loop of generation, evaluation, and modification under an optimization algorithm until the targeted objectives are achieved. Since this research focuses on multi-objective optimization techniques in which allows direct communication between multi-disciplinary simulation software, it is becoming a key factor in the design process. The proposed automated integrated process will allow the achievement of a set of optimal final form alternatives satisfying the specified, structural and energy objectives which provide great opportunities for the designer to select among different design options based on his preferences. Ultimately, increasing the number of optimum design alternatives, dealing with different levels of complexity in the architectural design process and promoting multi-disciplinary collaboration are the main benefits of the proposed approach.

PERFORMANCE ANALYSIS OF PARTIAL USE OF LOCAL OPTIMISATION OPERATOR ON GENETIC ALGORITHM FOR TSP

DJORDJEVIC, Milan* *UP DIST, Slovenia*
BRODNIK, Andrej *UP DIST, Slovenia*
GRGUROVIC, Marko *UP DIST, Slovenia*

In this paper we study the influence of hybridization of a genetic algorithm with a local optimizer on instances of a Traveling Salesman Problem from a TSPLIB. In tests we applied hybridization at various percentages of genetic algorithm iterations. On one side the less frequent application of hybridization decreased the average running time of the algorithm from 14.62 sec to 2.78 sec at 100% and 10% hybridization respectively, while on the other side the quality of solution on average deteriorated only from 0.21% till 1.40% worse than the optimal solution. We also studied at which iterations of the genetic algorithm to apply the hybridization. We applied it at random iterations, at the initial iterations, and the ending ones where the later proved to be the best.For testing our strategy and comparing it to other solutions we used the instances of symmetric TSP found on TSPLIB. In the first experiment we used 20 instances, with different complexity and a range from 100 to 439 cities per instance. We compared our method (grafted genetic algorithm (GGA)) using two different recombination operators: an edge map crossover (GGAemc) and a distance preserving crossover (GGAdpc). As the upper and lower limits on the quality of solution we used greedy heuristic and Concorde respectively. For the sake of completeness we compared our method also with 2-opt heuristic itself and with a canonical genetic algorithm. In the second experiment we studied what happens if we do not use local optimization in all generations - in test we used it in 10, 20, 30, 40, 50, 60, 70, 80 and 90 percents of the generations. Furthermore, for each percentage we applied local optimization in three different ways: at random generations, at the initial generations and at the ending ones. All experiments were conducted on a computer with Pentium(R) 2.8 GHz CPU and Windows 7 operating system. In our results we can not cross compare the running times of different solutions as they were implemented in different programming languages. On one hand we used as a development environment for GGA the Java written EAVisualizer, while Concorde is an AnsiC application. However, we can compare running times of GGA for different instances and cases explained before.

HARD AT PLAY: HOW PUZZLES CAN IMPROVE OPTIMIZATION TEACHING AND RESEARCH

INDRUSIAK, Maria Luiza Sperb* *Universidade do Vale do Rio dos Sinos - UNISINOS, Brazil*
INDRUSIAK, Leandro Soares *University of York, United Kingdom*

Teaching optimisation techniques at undergraduate level can be frustrating, because many students fail to grasp the sheer size of the solution space of apparently simple problems. For a newcomer, optimisation may look like a collection of nebulous techniques built on top of heavy mathematics. If one is unable to see how large a solution space can be, it is easier to dismiss optimisation as an unnecessarily complex academic practice. Those few students that are able to appreciate its importance are in turn baffled by the workings of the optimization metaheuristics, commonly seen as a kind of magic that can solve the most intractable problems. In this article, we report our experiences on using simple puzzles to facilitate the teaching and research of optimisation techniques. With a simple 25-tile game, we could show students the impracticality of brute force search, and managed to challenge them in such a way that they were keen to learn about optimisation heuristics that would enable them to find a solution. In this experiment, we chose to use a Genetic Algorithm (GA) because its evolutionary analogy is easy to grasp and the notions of mutation and crossover are directly applicable to the chosen puzzle. As part of the educational experiment reported in this paper, the puzzle and its solution using GAs has motivated informal discussions within the research group of one of the authors, leading the application of GAs to an open research problem, namely the mapping of tasks onto real-time multicore processors. This experience is also detailed in this article, as well as the positive feedback that results when undergraduate students realize that the same puzzle they are using as an educational gimmick has also helped leading-edge research in Computer Science.

SOLUTION OF FLOW SHOP SCHEDULING PROBLEMS USING THE DIFFERENTIAL EVOLUTION ALGORITHM

LOBATO, Fran Sérgio* *UFU, Brazil*
GEDRAITE, Rubens *UFU, Brazil*
NEIRO, Sérgio M. da S. *UFU, Brazil*

During the past two decades, there have been increasing interests on permutation flow shop with different types of objective functions such as minimizing the makespan, the weighted mean flow-time etc. The permutation flow shop is formulated as a mixed integer programming and it is classified as NP-Hard problem. This problem is normally classified as a complex combinatorial optimization problem, in which there is a set of jobs to be processed in a set of machines in the same order. We normally look for a special sequence of processing the jobs in the machines to minimize one or more criteria such as minimization of makespan, mean flow, etc. In this contribution, the Differential Evolution algorithm is used to minimize the makespan for the permutation flow shop scheduling problem. The results of the proposed method are compared with other evolutionary strategy. The preliminary results are compared with other approaches available and indicate that the proposed methodology characterizes a promising alternative for dealing with this type of problem.

GENETIC ALGORITHMS AND VASCULAR GRAFT OPTIMIZATION

CASTRO, Catarina F.* *IDMEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal, Portugal*
ANTÓNIO, Carlos Conceição. *IDMEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal, Portugal*
SOUSA, Luisa C. *IDMEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal, Portugal*

In the cardiovascular system development of atherosclerosis disease is mainly observed in regions of transient flow reversal, typically near bifurcations and along curved vessels. Atherosclerosis is a common type of arterial disease treated by surgical intervention using bypass grafts. One of the most prominent reasons for poor performance and failure of small and medium-sized grafts is the development of anastomotic intimal hyperplasia at the distal anastomosis. The optimization of graft and anastomotic configurations with regard to fluid and structural mechanics is the major target of this study. The blood is assumed to be a Newtonian fluid, with flow being pulsatile and turbulent. Genetic Algorithms are based on Darwin's theory of survival of the fittest. Once an initial population is created, new populations are generated following the previous one according to principles of reproduction, mutation and "survival of the fittest". This kind of algorithms starts with a randomly selected population of design points in the parameter space, where the values of the design parameters form a genetic string that uniquely represents each design point in the population. Then the method follows a sequence of generations, where the best design points in the population are considered to be the most fitted ones and are allowed to survive and reproduce. Ultimately, the method identifies optimal solutions as a family of design points that are non-dominated until the end of a predefined number of generations. In the present work a developed multi-objective genetic algorithm is considered in order to reach optimal graft geometries for idealized arterial bypass systems of fully occluded host arteries. Numerical results show the benefits of numerical shape optimization in achieving design improvements before a bypass surgery, minimizing recirculation zones formed at the distal corner of the bifurcation as well as at the toe and heel of the distal anastomosis minimizing the development of anastomotic intimal hyperplasia. However, further studies are needed to evaluate the practical applicability of this approach and the evaluation of the patency rate.

ARTIFICIAL BEE COLONY (ABC) FOR ENGINEERING PROBLEM OPTIMIZATION

GERHARDT, Eduardo *UFRGS, Brazil*
GOMES, Herbert Martins* *UFRGS, Brazil*

In this work, the performance of the Artificial Bee Colony (ABC) algorithm in engineering optimization problems is compared against those of other methods reported in the literature. The classic spring design optimization problem, and truss optimization on size and shape with frequency constraints problems were chosen for the numerical experiments. It is well knows that algorithm performance is problem dependent. Taking advantage of its flexibility, and based on related works, some modifications were implemented in the ABC algorithm. The results presented herein indicate that ABC algorithm is an effective global optimizer with relative high computational cost. However, its performance is comparable to the state-of-the-

art metaheuristics algorithms. Therefore, the applicability of ABC algorithm in engineering optimization problems is compromised with its cost-benefit ratio, by weighing the advantages against the disadvantages of its characteristic features.

SHAPE AND SIZE OPTIMIZATION OF MECHANICAL STRUCTURES WITH STRESS AND DYNAMIC CONSTRAINTS BY THE FIREFLY ALGORITHM

RODRIGUES, Eduardo Ribeiro *UFRGS, Brazil*
GOMES, Herbert Martins* *UFRGS, Brazil*

This work deals with the optimization of some mechanical structures using a metaheuristic algo-rithm called Firefly Algorithm. This work aims at reducing mass and eventually changing shape and size of such mechanical structures keeping material mechanical strengths and dynamic constraints such as natural frequencies on safe regions. The results are compared with those, when available, from literature that uses other algorithm for the optimization. As result, in some of the analyzed examples it is shown that the algorithm is more efficient than the other methods presented by the literature. This work is justified by the fact that the Firefly algorithm is metaheu-ristic and thus easily programmable. Furthermore, the algorithm does not require gradient eval-uations of the function to be optimized and has a random component that makes it robust against hard optimization problems likewise the handled problems of shape and size optimization with strengths and natural frequencies constraints.

GLOBAL OPTIMIZATION BASED ON METAMODELING USING RADIAL BASIS FUNCTIONS WITH ADJUSTMENT OF THE SHAPE PARAMETER C

SILVA, Edna Raimunda* *UNIFEI - Universidade Federal de Itajubá, Brazil*
MANZANARES-FILHO, Nelson *UNIFEI - Universidade Federal de Itajubá, Brazil*
CAMACHO, Ramiro Gustavo Ramirez *UNIFEI - Universidade Federal de Itajubá, Brazil*

Several methods of global optimization has been developed and intensively studied in recent decades, many authors suggested techniques that assist in the optimization process very efficiently. Regis and Shoemaker developed a strategy that accelerates the process of optimization, this technique consists in the construction and optimization of metamodels in order to reduce the number of calls of the objective function. The metamodels were constructed using radial basis functions and have been used differently in applications in engineering. Some radial basis functions require a shape parameter c to be adjusted by the user. In previous works it was observed that the shape parameter in the inverse multiquadrics and multiquadrics exerted a strong effect on the convergence rate of the optimization process. It presents a methodology for automating the shape parameter c so in order to obtain more robust and efficient metamodels for global optimization problems. The paper focus is in the implementation of a leave-one-out cross-validation for optimizing the shape parameter as suggested by Rippa, becoming unnecessary arbitrary choice of the c. The scheme is based on the minimization of a suitable cost function that ideally has the same behavior as the error function approximation. In each iterative step the shape parameter that minimizes this cost function is chosen for constructing a global metamodel using the costly function data already available. For the process of optimization of the shape parameter c, will be developed a subroutine that set ranges of c based on the dimension of the problem. For the optimization global process, the Controlled Random Search Algorithm (CRSA) is employed for optimizing the metamodel approximations. Comparative numerical results are presented for Dixon-Szegö functions and also real world functions related to engineering design, for example, blade cascade case.

MULTIOBJECTIVE OPTIMIZATION OF FINITE QUEUEING NETWORKS

BRITO, N. L. C. *Universidade Estadual de Montes Claros, Brazil*
DUARTE, A. R. *Universidade Federal de Ouro Preto, Brazil*
CRUZ, F. R. B.* *Universidade Federal de Minas Gerais, Brazil*

In this paper a multi-objetive algorithm is presented to simultaneously optimize the total number of buffers, the overall service rate, and the throughput of a general-service finite queueing network. These conflicting objectives are optimized by means of a multi-objective genetic algorithm, designed to produce solutions for more than one objective. Some computational experiments that were conducted will be shown, in order to determine the efficacy and efficiency of the approach. Some insights are given.

GLOBAL OPTIMIZATION METHOD TO PARAMETERS CALIBRATION APPLIED ON ENGINEERING SYSTEMS

ELHAJJ, Marwa* *UVSQ, France*
YOUNES, Rafic *UVSQ, France*

The aim of our study is to develop an approach to calibrate a complex multi domain system. This approach respects the real functioning of the model, the accuracy of the results and the minimizing of the measurement's number thus the cost of the experimental phase. In this paper, a new method based on the exchange between the genetic algorithm (GA) on Matlab and the simulated model on a simulation software, are proposed and evaluated for this issue. An example was used to verify if this method was able to converge to that optimal solution. In order to improve this method, a success study for the optimization of the measured outputs' number by applying a sensibility analysis was applied to identify a new fitness of the genetic algorithm. Finally the results show that the hybridation between genetic algorithm and sensibility analysis is an integrated solution.

PARAMETER ESTIMATION WITH OPPOSITE DIFFERENTIAL EVOLUTION APPLIED TO LIQUID CHROMATOGRAPHY

HERNÁNDEZ TORRES, Reynier *Instituto Superior Politécnico José Antonio Echeverría, Cuba*
IRIZAR MESA, Mirtha *Instituto Superior Politécnico José Antonio Echeverría, Cuba*
LLANES SANTIAGO, Orestes *Instituto Superior Politécnico José Antonio Echeverría, Cuba*
T. CÂMARA, Leôncio Diógenes* *Universidade do Estado do Rio de Janeiro, Brazil*
DA SILVA NETO, Antônio José *Universidade do Estado do Rio de Janeiro, Brazil*
ZUMALACÁRREGUI DE CÁRDENAS, Lourdes Margarita *Instituto Superior Politécnico José Antonio Echeverría, Cuba*

In many biotechnological processes, complex inverse problems related to the optimization, scalability and parameter estimation are present. Computational models of these processes are usually characterized by an absence of trustworthy parameter values. Chromatographic models are an example of this problem. Usually, experimental data is used to estimate these missing parameters. Many optimization techniques have been used to solve this problem. Metaheuristics are global optimization algorithms which seek and find good solutions, in a reasonable computational cost. In this work, a recent algorithm, opposite differential evolution, is applied to the problem of estimating parameters in liquid column chromatography. The effectiveness of this algorithm is analyzed, through a comparison, based on different statistical criteria, with other basic algorithms (genetic algorithms, differential evolution, particle swarm optimization, ant colony optimization). It is used a case study of a single component (a-lactoalbumina), using the general rate model with five parameters.

Civil Engineering

PRODUCTION SCHEDULING IN PROPORTIONATE MACHINES WITH SETUP TIMES AND SEQUENCE DEPENDENT JOB DEADLINES

DAZA-ESCORCIA, Julio Mario* *Corporación Politécnico de la Costa Atlántica, Colombia*
FERRER-VÁSQUEZ, Mario *Alfaisal University, Riyadh, South Africa*

This paper presents the design of an alternative metaheuristic for multi-type problems Qm|rj,sj,k,dj|Lex{Cmax,SJj=1Cj}. To develop the experimental work proposed metaheuristic algorithm development of two phases: i) to build and ii) optimize the scheduling. In the first stage are assigned jobs by balancing heuristic (RHE). The second phase is to diversify the solutions obtained in the previous stage using criteria metaheuristic genetic algorithms (GA), then enhance these through the combinatorial optimization technique tabu search (BT), thus escaping the local optimum and generate a global optimum. This alternative was applied to random instances and was compared with similar heuristics used to solve the problem in question, obtaining satisfactory results.

OPTIMIZATION OF MASONRY UNITS FOR SINGLE LEAF WALLS USING A GENETIC ALGORITHM

SOUSA, Luisa C.* *Faculty of Engineering, University of Porto, Portugal*
CASTRO, Catarina F. *Faculty of Engineering, University of Porto, Portugal*
SOUSA, Hipólito *Faculty of Engineering, University of Porto, Portugal*
ANTÓNIO, Carlos Conceição *Faculty of Engineering, University of Porto, Portugal*

The purpose of this paper is to present an optimized lightweight concrete masonry unit, made with expanded clay LECA*, for single leaf external walls of buildings. The optimization goal is to build economic single leaf walls with good thermal performance without compromising the wall structural properties. From an economic and environmental conservation point of view, it is more beneficial to design walls of buildings with high thermal insulation characteristics obtained from thermal improved units (bricks or blocks) than the currently followed practice of no insulate buildings or add insulation layers. The use of cavity or double leaf walls with insulating materials improves walls thermal resistance but the installation of such materials is expensive and requires skilled labor. The referred solutions will result in long-term benefit of reducing the construction impact in terms of energy consumption during life cycle. Concrete blocks can be an interesting masonry material, whose thermal behaviour can be very improved by introducing holes or air gaps in a concrete block and optimizing their topology. At the same time the thermal conductivity of the concrete can be reduced replacing the traditional concrete by a lightweight one. A developed computational method searches a new topology for lightweight concrete blocks that will perform according to today's normative requests. Design variables such as number of vertical and horizontal webs, vertical and horizontal shell's and web's thicknesses, staggered and in line joints and presence or location of strip bed joints are considered. The development of this new block takes also into account laying requirements, production and technological constraints. In the optimisation problem three-dimensional finite element computer simulations are performed to calculate wall thermal performance characterized by the thermal transmittance of masonry. A genetic evolutionary algorithm iterates over the finite element direct analysis and an optimal solution of vertically perforated blocks is presented demonstrating the applicability and efficiency of the optimization method.

A DETERMINISTIC SEGMENT-LINKED OPTIMIZATION MODEL FOR ROAD NETWORK MAINTENANCE MANAGEMENT

FERREIRA, Adelino* *Department of Civil Engineering, University of Coimbra, Portugal*
SOUZA, Ricardo *Department of Civil Engineering, University of Coimbra, Portugal*

This paper presents a deterministic segment-linked optimization model to be used by the Decision-Aid Tool (DAT) of Pavement Management Systems to support decisions of road administrations. The DAT is constituted by the following components: the objective of the analysis; the data and the models about the road pavements; the constraints that the system must guarantee; and the results. Different objectives can be considered in the analysis, including the minimisation of agency costs (maintenance and rehabilitation costs), the minimisation of user costs, the maximisation of the residual value of pavements at the end of the planning time-span, or any combination of them. The quality of road pavements is evaluated by the PSI index (Present Serviceability Index), representing the condition of the pavement in function of the following parameters: longitudinal roughness, rutting, cracking, surface disintegration, and patching. This pavement quality index is computed by using a modified version of the PSI AASHTO (American Association of State Highways and Transportation Officials) equation. The DAT uses the HDM-4 deterministic pavement performance models to predict the future quality of pavements. The DAT is constituted by a deterministic segment-linked optimization model that is solved by an heuristic method based on genetic-algorithm principles. The DAT allows to define, for a given road network and over a given number of periods, the best M&R actions to be taken in each segment and period. The optimization model behind the DAT uses decision variables that maintain the identity of pavement sections in the network and lead to maintenance and rehabilitation policies that are easy related to these sections. In this way, the translation of network-level policies into project-level decisions is easier to make. The DAT also allows the user to simulate maintenance and rehabilitation strategies, only defined by the user or changed from the solution given by the model, for each road pavement, for a set of road pavements or for the whole road network, and to visualize the results of its application for one predefined planning time-span. The application of the DAT to a case study (road network of Viseu) presented very good results as it will be demonstrated in the paper. The final part of the paper contains a reflection on the main difficulties encountered so far and presents the developments planned for the near future.

HARMONY SEARCH ALGORITHM APPLIED TO THE OPTIMIZATION OF REINFORCED CONCRETE COLUMNS

FLEITH DE MEDEIROS, Guilherme *Universidade de Passo Fundo, Brazil*
KRIPKA, Moacir* *Universidade de Passo Fundo, Brazil*

The search for a design that meets both performance and safety, with minimal cost and lesser environmental impact was always the goal of structural engineers. In general, the design of conventional reinforced concrete structures is an iterative process based on rules of thumb established from the personal experience and intuition of the designer. However, such procedure makes the design process exhaustive and only occasionally leads to the best solution. In such context, this work presents the development and implementation of a mathematical formulation for obtaining optimal sections of reinforced concrete columns subjected to uniaxial flexural compression, based on the verification of strength proposed by the Brazilian standard NBR 6118 (ABNT 2007). To minimize the cost of the reinforced concrete columns, the Harmony Search Algorithm (HS) was used, in which the amount and diameters of the reinforcement bars and the dimensions of the columns cross sections were considered as discrete variables. Harmony Search is an optimization method developed by Geem, Kim and Loganathan in 2001, inspired by the observation that the aim of music is to search for a perfect state of harmony. The search process is compared to a musician's improvisation process. The results obtained with HS were compared to those obtained from the conventional design procedure and other optimization methods, in an attempt to verify the influence of resistance class and material costs on the optimal design of reinforced concrete columns subjected to uniaxial flexural compression. Some initial analyses indicate that HS outperforms Simulated Annealing, previously used by the authors to solve analogous problems.

INFLUENCE OF SILICA FUME ON THE PROPERTIES OF SELF-COMPACTING CONCRETES

ALSANUSI, Salem K.* *University of Benghazi, Lybia*
ESMOUE, Hakeem *University of Tripoli, Lybia*
JOUMA, Waneasa *University of Benghazi, Lybia*

Since Silica fume can make a significant contribution to early-age strength of concrete where it improves concrete in basic pozzolanic reaction, and in a micro filler effect. In additional silica fume improves bonding within the concrete and helps reduce permeability, it also combines with the calcium hydroxide produced in the hydration of Portland cement to improve concrete durability. Therefore we have focused in this paper on the influence of silica fume on self compacting concrete. The main objective is to determine the effect of silica fume on self compacting concrete in the fresh and the hardened state. An experimental program was carried out by replacing cement with different percentages of silica fume at different constant water-cement ratio keeping other mix design variables constant. The results showed that the tensile, compressive and flexure strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the water-cement ratio of the mix. Based on the results, a relationship between split tensile, compressive and flexure strengths of silica fume concrete was developed. Also, by using statistical methods relationships between U-box index, L-box index, V-funnel, and inverted slump test to selected silica fume percentage have been established.

Composite Material Optimization – Smart Structures

OPTIMIZATION OF STACKING SEQUENCE OF COMPOSITE LAYERS IN CIRCULAR HYBRID TUBES UNDER AXIAL IMPACT LOAD

MIRZAEI, Mostafa *Islamic Azad University, Damavand branch, Iran*
AKBARSHAHI, Hossein *Amirkabir University of Technology, Iran*
SHAKERI, Mahmood* *Amirkabir University of Technology, Iran*
SADIGHI, Mojtaba *Amirkabir University of Technology, Iran*

Thin-walled structures are widely used as energy absorbing devices in many applications such as transportation, personal safety and packaging industries. Circular and square tubes have been gained extensive usages in the field of energy absorption in impact loads and represent the most widespread shape of collapsible energy absorbing components. These structures undergo large plastic deformations and collapse progressively to convert impact energy to irreversible energies in order to build safer positions. On the other hand, necessity of making these structures lighter, specially in transport applications, has caused usages of composite materials to extend and introduced a new group of these structures in the form of hybrid tubes made of metal and composite materials. Reinforcing metal tubes with composite layers improves their energy absorption capability and affect the crashworthiness parameters (absorbed and specific energy, maximum and mean crushing load) considerably. Experimental and numerical results show that in addition to geometrical dimensions of metal tube, stacking sequence of composite layers significantly affect the crashworthiness parameters of hybrid tubes. So, from energy absorption viewpoint the optimization of crashworthiness behavior of hybrid tubes is inevitable. In this paper multi-objective crashworthiness optimization of circular hybrid tubes under axial impact load is presented with the aim of maximizing the specific energy and load efficiency factor (mean load/ maximum load) by Non-dominated Sorting Genetic Algorithm-II (NSGA-II). A circular aluminum tube with the length of 216 mm, diameter of 108 mm and thickness of 3 mm is considered which is reinforced by four composite layers with the layup of . Fiber angle orientation of middle composite layers ( ) are selected as the design variables which are measured from the tube axis. In order to reduce the occupant injury when passenger vehicles are considered, the mean crushing load is constrained to not exceed from an allowable limit. To construct the response surfaces of objective parameters in terms of design variables, back-propagation neural network is used. Training and testing of the neural networks are carried out by obtained results from numerical simulations by ABAQUS finite element code. To validate the numerical simulations, the results are compared with the experiments which show reasonably good agreement. At last, optimum results are presented as Pareto frontier.

MATERIAL IDENTIFICATION OF VISCOELASTIC CORE MATERIALS IN SANDWICH STRUCTURES

ARAUJO, Aurélio L. *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*
MOTA SOARES, C.M.* *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*
MOTA SOARES, C.A. *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*
HERSKOVITS, José *COPPE/UFRJ - Federal University of Rio de Janeiro, Brazil*

The inverse problem of estimating viscoelastic material parameters is addressed in this paper with application to sandwich plates with a viscoelastic core and laminated composite face layers. We use a sandwich plate finite element model, where the viscoelastic properties of the core layer are modeled using the complex modulus approach. Fractional derivative viscoelastic material models are used for the sandwich core frequency dependent properties due to the fact that these models use a minimal set of parameters, which are the ones to be estimated. The sandwich is modeled using a plate finite element model with a layerwise approach, where the laminated composite face layers are modeled with a first order shear deformation theories and the viscoelastic core is modeled using a higher order shear deformation theory with cubic expansion of the in-plane displacements in the thickness coordinate. The finite element is an eight node serendipity plate element with 13 degrees of freedom per node. The inverse problem is solved using a gradient based approach with FAIPA - Feasible Arc Interior Point Algorithm. Parameter estimation is conducted using only natural frequencies and corresponding modal loss factors.

OPTIMAL POSITIONING OF PIEZOELECTRIC PATCHES IN SANDWICH STRUCTURES FOR MAXIMUM DAMPING USING THE DIRECT MULTISEARCH METHOD

ARAUJO, Aurélio L..* *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*
AGUILAR MADEIRA, J.F. *IDMEC/IST and ISEL, Portugal*
MOTA SOARES, C.M. *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*
MOTA SOARES, C.A. *IDMEC/IST - Instituto Superior Técnico, Technical University of Lisbon, Portugal*

Optimal location for maximum modal damping of surface bonded piezoelectric patches in sandwich plates with viscoelastic core and laminated face layers is addressed using multiobjective optimization, with the purpose of maximizing active damping using co-located piezoelectric patches with negative velocity feedback control. The material properties of the viscoelastic core of the sandwich plate are assumed to be frequency dependent and a fractional derivative viscoelastic model is assumed for material behavior. The elastic face layers of the sandwich plate are made of laminated composite materials and the finite element model for the plate is based on a mixed layerwise formulation, where the core is modeled according to a higher order shear deformation theory and each of the elastic faces and piezoelectric patches according to a first order shear deformation theory. The modal response of the sandwich plate is obtained through the solution of a non linear eigenvalue problem. The piezoelectric patches are assumed to be co-located and their optimal positioning for maximum modal damping is determined using the Direct MultiSearch (DMS) solver for derivative-free multiobjective optimization. DMS is a solver for multiobjective optimization problems which does not use any derivatives of the objective functions. It is based on a novel technique called direct multisearch, developed by extending direct search from single to multiobjective optimization.

OPTIMAL SHAPE OF FIBERS USING FEM AND BEM

PROCHAZKA, Petr P.* *CTU in Prague, Civil Engineering, Czech Republic*

Classical problem of localization and homogenization on the micro-level is used for determining an optimal shape of fibers in a symmetric composite structure. Material properties of fiber and matrix in the composite examined are known a priori, as they are given from the materials applied for the fabrication of the structure. The shape of fiber is sought with the goal to ensure both the minimum stress and deformation. It appears that the minimum for Lagrangian ensures this requirement. A constraint appears to be necessary for practical reasons and is applied in such a way that the area (volume) of the fiber is given a priori and fixed. In most cases, an additional requirement has to be introduced suppressing possible crossing the interfacial boundary of fiber and matrix with the external boundary of the domain of composite. For this reason, restrictions on the shape of phases should be introduced, such as the bounds on diameters or tangential inclinations of certain directions of the phase boundaries. Different formulations are necessary for different numerical tools. Considered are finite elements and boundary elements, continuous formulations of which

are presented. Approximate solution then follows the concrete problems. The design parameters are always beams their origin is centered in the symmetric domain with a local coordinate system in the unit cell characterizing the micro-level of the composite. The problem assumes star-shaped domain of the fibers. This assumption does not cause any loss of generality. The finite element method starts with the classical ideas by Suquet and Eshelby, while the problem posted in terms of boundary elements utilizes the polarization tensor (or similar), as a homogeneous material properties are required in the boundary element procedures. The process of optimization uses the formulation with Lagrangian multipliers constraining the area of fibers. The self-sustained problems are quite newly posted. Large scale of examples is to be presented to show and point out the ability of the procedures put forward. It appears that the shape of fiber in a symmetric composite unit cell is dependent on the material stiffnesses or compliances of the phases, on the volume frictions and the shape of the unit cell. Financial support of the Grant agency of the Czech Republic, grant number P105/00/0266 is gratefully acknowledged.

SHAPE AND TOPOLOGY OPTIMIZATION OF MULTI-LAYERED COMPOSITE MATERIALS

DELGADO, Gabriel* *Ecole Polytechnique, France*
ALLAIRE, Grégoire *Ecole Polytechnique, France*

This work is devoted to multi-layered composite design in structural optimization. Given a stacking sequence and fiber orientation, we determine the optimal shape of each layer composed by two orthotropic phases. Each layer is modeled as a linearly elastic membrane. The objective function to be minimized is the weight of the composite structure under a rigidity constraint (compliance or minimum stress). We propose a numerical algorithm for shape and topology optimization based on the level set method coupled with the shape and topological derivatives. Difficulties for elastic low contrast shape derivative and anisotropic topological derivative calculations are addressed. A 2-d airplane fuselage section test case is discussed.

ADAPTIVE TABU SEARCH IN SENSITIVITY OF BUCKLING LOADS TO IMPERFECTIONS IN CONICAL SHELLS

BLACHUT, Jan* *The University of Liverpol, Mechanical Engineering, United Kingdom*

Conical shells used in off-shore and in petrochemical on-land applications are frequently designed with buckling failure in mind. This in turn is dependent on sensitivity of buckling loads to the initial geometric imperfections. A recent experimental and numerical study has shown that buckling load of short and relatively thick steel cones subjected to combined action of external pressure and/or axial compression is affected by both inward and outward shape deviations from perfect geometry. It has been shown that the outward shape deviations can, in some situations, lead to a greater reduction of the load carrying capacity than the inward shape deviations, and this appears to be a new development not generally anticipated or known. Over the last decade or so, there has been a trend to convert imperfection-sensitive structural components into imperfection-insensitive elastic structures. But certain structural elements like externally pressurized domed ends can remain geometrically imperfect and yet fail at the same buckling load as nominally the same and geometrically perfect counterparts. The paper studies the use of Tabu Search to structural optimization of non-reinforced steel conical shells. The design variables are: (i) arbitrary imperfections of inward and outward profiles, and (ii) arbitrary magnitudes of shape deviations. The inward and outward distortions can freely interact. The profile of the imperfection which leads to the largest drop of the buckling strength (i.e., optimal) is sought, and this as such would be equivalent to the lower bound response curves available for other structural elements. Two Tabu Search approaches are investigated: (i) static search, and (ii) adaptive search. The role of free parameters to be tuned (neighbourhood size, tabu tenure, aspiration, size and evolution of tabu patch size) are discussed. The method itself uses the standard, self-standing FE code as the re-analysis tool. Results are provided for mild steel cones with the large radius, r2, to the wall thickness, t, ratio: r2/t ˜ 30, the radius to height, h, ratio of: r2/h ˜ 1.0, and the cone angle ß ˜ 15 deg.

SELFISH GENE THEORY AND MEMETIC ALGORITHMS: A FUSION OF CONCEPTS FOR ROBUST DESIGN OF HYBRID COMPOSITES

ANTÓNIO, Carlos Conceição* *IDMEC-Faculdade de Engenharia, Universidade do Porto*, *Portugal*

The memetic algorithms (MAs) were firstly introduced as joint application of population-based global search and heuristic learning, where the latter is often referred to as a meme associated with local search. Sometimes they are referred as population-based meta-heuristic search methods, inspired by Darwin's theory of natural evolution and Dawkins' notion of meme defined as a unit of cultural evolution. This genetic and cultural evolutionary symbiosis of MAs has been materialized into the form of a hybrid global-local approach improving both exploration and exploitation properties of search. Instead local search as performed in MAs, the selfish gene algorithm (SGA) follows a different learning scheme where the conventional population of individuals is replaced by a virtual population of alleles. In this paper a fusion of concepts proposed by MA and SGA are implemented. The proposed algorithm is based on co-evolution of populations supported by Lamarckian and the Baldwinian learning procedures. All individuals generated belong inherently to an enlarged population with age structure. Assuming that the population maturity and potentiality follows a Normal distribution the parent selection is done according to its probability. The evolution of the age structured population is based on the SG theory where the population can be simply seen as a pool of genes and the individual genes fight for the same spot on the chromosome in the genotype. The frequency of appearance of an allele increases the success rate overall. The survival of the fittest depends on genes, not individuals. The SGA performs its effects on the statistical parameters of the virtual population along the evolutionary process. Each new solution is implicitly generated by changing the frequencies or the probabilities of the alleles or possible genes. Assuming that the age structured population is the virtual population continuous statistical parameters of allele's population are updating at each generation. Thus, most promising alleles are selected for genes. Then, generation procedure of new individuals following SG theory is based on a pseudo-crossover scheme with changed Mating Selection and Offspring Generation mechanisms influenced by best alleles in age-structured Virtual Population. Aiming to discuss the capabilities of the proposed approach to deal with robust design optimization of hybrid composite structures a numerical example is presented.

EFFECTIVE DESIGN OF RECTANGULAR SANDWICH PLATE WITH A CORRUGATED CORE

WITTENBECK, Leszek* *Institute of Railway Vehicles "TABOR"*, *Poland*
MAGNUCKI, Krzysztof *Poznan University of Technology*, *Poland*
KULIGOWSKI, Pawel *Institute of Railway Vehicles "TABOR"*, *Poland*

Lightweight railway car body structures enhaces fuel efficiency and decreases maintance costs. Many investigators have been focused on reducing the weight of the railway vehicles and simplifying the construction to reduce assembly times and manufacturing costs. Thin-walled structures such as sandwich plates have been used to provide high strength and rigidity to weight ratio. The subject of the paper is a rectangular sandwich plate with a corrugated core. Strength and stability problems of the plate are described. Analytical model is formulated. Rigidities are derived and governing equation is solved. Local and global buckling constraints are formulated. Statement of optimal problem includes: parameters, constraints, objective function - optimization criterion.

DESIGN OPTIMIZATION OF REPAIRED COMPOSITE STRUCTURES FOR AEROSPACE APPLICATIONS: CONCEPT AND IMPLEMENTATION

GURVICH, Mark R.* *United Technologies Research Center*, *United States of America*
JAGDALE, Vijay N. *United Technologies Research Center*, *United States of America*

Existing design methods to optimize composite structures are primarily focused on new untouched components. However, typical composite structures are susceptible to numerous damages in operation, transportation, and maintenance with follow-up repairs. Although these repairs are usually the weakest zones of the composite structures, their designs are often over-conservative since available modeling capabilities are still semi-empirical and based primarily on generated field experience and engineering common sense. Recent progress in modeling of repaired zones provides potential opportunity for corresponding design optimization. Thus, the objective of this study is to develop a general concept of optimization of repaired

composite structures, demonstrate its efficient computational implementations, and illustrate potential benefits of such optimization on representative examples of aerospace composite structures. The proposed concept captures processes of both damage initiation and damage growth using cohesive elements (CE) in FEA models of the repaired zones. Robust computational implementation of damage process is demonstrated even for relatively complex damage patterns in the repaired zones. Major characteristics of the model, such as sizes and orientations of repair surfaces, material properties, lay-ups, etc. are considered as parameters of optimization. Numerical results of optimization are shown on example of a representative repair scenario under different loading conditions, and generated trends are discussed in detail. Finally, opportunities for probabilistic optimization are considered to account for uncertainty of loading conditions and variability of material properties.

PROPERTIES OF THE COST FUNCTIONAL IN FREE MATERIAL DESIGN

BARBAROSIE, Cristian* *CMAF, Univ. of Lisbon, Portugal*
LOPES, Sérgio *ISEL, Instituto Politécnico de Lisboa, Portugal*

The present work studies cost functionals used in the framework of free material design. Special emphasis is given to the cost functional emerging from the homogenization theory, equal to the minimum amount of material needed to build a certain composite by mixing two base materials. This particular functional is proven to be non-convex, implying it is not lower semicontinuous with respect to the weak* topology, in spite of being lower semicontinuous with respect to the H-topology. For mixtures between material and void, the same functional is shown to be subadditive only in two dimensions; also, it fails to be positively homogeneous regardless of dimension.

OPTIMAL DESIGN OF SANDWICH FUNCTIONALLY GRADED STRUCTURES USING PARTICLE SWARM OPTIMIZATION

BARBOSA, I.C.J.* *ISEL/ADEM – Instituto Superior de Engenharia de Lisboa; IDMEC/LAETA-Instituto de Engenharia Mecânica, Portugal*
LOJA, M.A.R. *ISEL/ADEM – Instituto Superior de Engenharia de Lisboa; IDMEC/LAETA – Instituto de Engenharia Mecânica, Portugal*

Dual-phase functionally graded materials are a particular type of composite materials, whose properties conceptually vary continuously, depending at each point on the composition distribution of its two constituents. These materials are known to provide superior thermal and mechanical performances when compared to the traditional laminated composites, because of its continuous properties variation characteristic, which enables among other advantages smoother stresses distribution profiles. Moreover, it is well known that abrupt transitions in material properties within a composite structure can cause stress concentrations, which can be mitigated by gradually varying the microstructure and/or composition of materials in a gradient architecture. Therefore, associated to a growing interest in applying these materials on the most diverse application fields, different requirements arise to obtain improved material and structural configurations on each specific application. With this work it is intended, in a first stage, to characterize the influence on the structure mechanical behaviour, of considering either a discretely graded effective properties distribution across the thickness or a continuously graded varying scheme. These two possibilities reflect, in practice, different manufacturing solutions, with consequences that are important to quantify. In a second phase of this work, particle swarm optimization technique is considered to achieve improved, optimum configurations for these functionally graded sandwich structures, according to specific conditions and constraints. To illustrate the performance and adequacy of the optimization technique used as well as the modelling of the beam structure, a set of illustrative examples will be presented.

MULTISCALE FINITE ELEMENT DESIGN AND OPTIMIZATION OF COMPOSITE POROELASTIC AND POROUS PIEZOELECTRIC MATERIALS

NASEDKIN, Andrey V.* *Southern Federal University, Russian Federation*
NASEDKINA, Anna A. *Southern Federal University, Russian Federation*

The paper deals with computer design of multiscale composites, that consist of porous elastic and electroelastic media of regular and irregular structure, and optimization of its phase components at macroscale. At the first stage of the modeling the models of elastic skeleton of the representative volumes are built so that they

take into account some characteristics of porous and multiphase anisotropic composite structures. With the help of the effective moduli method the effective properties of anisotropic composite are determined and with the help of finite element method several poroelasticity problems for the representative volume with special boundary conditions are solved. Different models of skeletons were considered, such as random pore generation, special methodologies for partially random structure generation that support the connectivity of the skeleton, beam and shell models, and etc. Then at macrolevel the fibrous composites of periodic structure are investigated, at that one of the phases is considered as porous elastic and/or electroelastic material with effective properties defined at the microlevel. Here using finite element method the problems at the periodicity cell are solved and optimizing computations are carried out in order to define the most effective sizes and material properties of phase components from a position of strength and for optimization of the most important working characteristics of fibrous composite. The finite element computations were implemented using the computation complex ANSYS, and special set of computer programs were written in marcolanguage APDL ANSYS. At that, the generation of the range of the structures for representative volumes were carried out using separate programs in C and subsequent transfer of solid and finite element models to ANSYS. In order to illustrate the implementation of the approaches developed, some biomechanics poroelastic models of trabecular and compact bone tissues and some models of piezoelectric porous composites with application to the problems of effective energy piezogeneration were investigated. The technologies developed enable to analyze multiphase anisotropic electroelastic, poroelastic and thermoelastic (according to porothermoelastic analogy) composites with regard to its microstructure and study the problems for macrovolumes of the composites with inclusions of microheterogeneous materials.

OPTMIZATION OF ACTIVE-PASSIVE PIEZOELECTRIC NETWORKS PARAMETERS

LEAL DOS SANTOS, Heinsten Frederich* *EESC-USP, Brazil*
TRINDADE, Marcelo Areias *EESC-USP, Brazil*

Piezoelectric materials can be used either as actuators connected to an appropriate control law to provide active vibration control or as sensors connected to shunt circuits to provide passive damping. In the last decade, research was redirected to combined active and passive vibration control techniques. One of these techniques, so-called Active- Passive Piezoelectric Networks (APPN), integrates an active voltage source with a passive resistance-inductance shunt circuit to a piezoelectric sensor/actuator. It has been shown that combined active-passive vibration control allows better performance with smaller cost than separate active and passive control, provided the simultaneous action is optimized. On the other hand, like for purely passive shunted piezoelectric damping, most of the studies concerning APPN focus on the optimization of the electric circuit architecture and components. In particular, a main issue for resonant shunt circuits is the high values of inductance needed when low frequency modes are to be controlled which normally requires the use of a synthetic inductance and, also, the need for a fine tuning of the circuit parameters with structural natural frequencies and electromechanical coupling coefficient. Another issue is the sensitivity of the control design and performance to the circuit components. This work propose a optimization of the electric shunt circuit parameters to improve the better performance of the control vibration for passive damping using a shunt circuit and for active-passive damping using a APPN control.

OPTIMIM DESIGN OF COMPOSITE PRESTRESSED CONCRETE GIRDER RAILWAY BRIDGES

AL-NUAIMI, Amer *Nottingham trent university, United Kingdom*
MOHAMMAD, Fouad* *Nottingham Trent University, United Kingdom*

Abstract This paper deals with the formulation of design optimisation of pretsressed concrete bridges. The bridge is of a slab-on-girder type, hence modeled as an equivalent orthotropic plate. The whole bridge system is considered as a simply supported right angle plate. Following linear elastic behaviour, the governing fourth order differential equation of the plate for patch load is solved in order to find out load distribution on the girders forming the bridge as well as the deflections and internal forces at critical sections of the whole bridge. The optimisation problem is formulated for various cross sectional geometries including rectangular, symmetrical I, unsymmetrical I, box, T and inverted T sections. The design variables are the main cross sectional dimensions, prestressing force and tendon eccentricity. The objective function comprises the cost of concrete material, formwork and prestressing steel tendons. The constraint functions are set to satisfy design requirements as per British Standards for bridges (BS 5400). Nonlinear optimisation

method based on sequential unconstrained minimisation technique (SUMT) is employed to achieve optimum bridge configuration for specific design parameters of span length, concrete compressive strength and railway loading patterns. A purpose built computer program is set up to carry out the solution of the design optimisation problem efficiently in terms of time and effort. A typical example of unsymmetrical I-section having a small bottom flange as compared to the top flange width with composite deck effect is presented. The results show that the total cost increases as the span increases due to the increase of the initial prestressing force. Furthermore, the total cost decreases as the concrete compressive strength increases in spite of the increasing of the prestressing force. This is due to decrease of the overall depth, top and bottom flange widths, hence leading to a smaller girder size. Such finding will encourage engineers to adopt high strength concrete for bridges as it will help reducing not only the initial cost but also the life cycle cost of the bridge over its entire life.

DESIGN OF INTERFACES TO MAXIMIZE MATERIAL PROPERTIES IN POLYMER COMPOSITES

TANNENBAUM, Rina *Boston University*, *United States of America*
JASIUK, Iwona *University of Illinois at Urbana*, *United States of America*
JACOB, Karl* *Georgia Institute of Technology*, *United States of America*
CIPRIRI, Dan *Georgia Institute of Technology*, *United States of America*

Reinforced polymers are often used in many applications for increased mechanical properties. Addition of particles or fibers usually increases mechanical properties, but not always. Thus, understanding the behavior of the interface connecting reinforcements and matrix is critical in engineering particle reinforced polymers. The mechanical properties are assumed to be affected by the conformation of polymer chains around the particles. Optimizing molecular architecture close to the reinforcements is critical to improving overall mechanical properties of the composite system. This problems falls under the general materials design area, where materials and composition are optimized to generate required properties, rather than using available materials and changing the design to meet the requirements. In this talk, an account of optimizing polymer/ particle interactions will be given as a general materials design problem.

Energy Generation and Transmission

THE IMPACT OF INEXACTNESS IN NONSMOOTH OPTIMIZATION: AN EMPIRICAL ANALYSIS WITH APPLICATION TO POWER MANAGEMENT PROBLEMS

SAGASTIZABAL, Claudia* *IMPA, Brazil*

The optimal management of many power units is a challenging problem, from both economical and mathematical points of view. Consider a mix of power plants (hydraulic, thermal -fuel or nuclear based-, eolian or other renewable), whose generation is to be optimized over certain time horizon. Each plant is formed by several units, such as generators or turbines. The operation of each plant involves a cost to be minimized that is usually separable by units. There are also constraints to be satisfied, of dynamic or static nature. Dynamic constraints refer to specific limitations of each power technology, usually coupling consecutive time steps. By contrast, static constraint couple all plants at a single given time, for instance, requiring that the production of the whole mix satisfies the demand at each time step. For this type of problems, Lagrangian relaxation is a convenient tool to bring on separability. The negative of the dual function is convex and nonsmooth. With price decomposition, evaluating the dual function and getting one subgradient involves finding a minimizer of individual subproblems, corresponding to the different units that compose the power mix. This feature makes the dual problem suitable for oracle based methods, that is, algorithms designed on the knowledge, at each iterate, of the function value and of one subgradient. An optimum of the dual problem is used to establish price cap regulations in a competitive environment, or to define electricity prices in a centralized system. In general, the goal is to obtain both accurate primal and dual solutions. In a decomposition framework like the one presented above, bundle methods appear as one of the best choices for solving the dual problem. The last generation of bundle methods is able to handle inexact function and subgradient evaluations. Having a nonsmooth method able to deal with inexact information makes it possible to accelerate calculations, for instance by exiting subproblems before optimality, or even skipping some subproblem solution. Naturally, both the dual multipliers and the primal points obtained when solving the dual problem are then “polluted” in a way that is not yet well understood from a theoretical point of view. We will investigate this issue, keeping in mind the special structure of the problem under consideration.

ESTIMATING THE PROBABILISTIC CONTENTS OF GAUSSIAN RECTANGLES FASTER IN JOINT CHANCE CONSTRAINED PROGRAMMING FOR HYDRO RESERVOIR MANAGEMENT

VAN ACKOOIJ, Wim* *EDF R&D, France*
ZORGATI, Riadh *EDF R&D, France*

In this work, we deal with a hydraulic reservoir optimization problem with uncertainty on inflows in a bilateral joint chance constrained programming setting. In particular these inflows will have a persistency effect coming from a causal time series model with Gaussian innovations. Despite the nice trade-off between robustness and cost coming from the joint chance constraint programming approach, its industrial use is still limited by important computation time. Recent advances in bundle methods, incorporating inexact evaluation of function values and gradients, allow us to decrease this computation time by a factor 20. The bottleneck for obtaining gradients and function values quickly is the evaluation of the probabilistic contents of a rectangle. This evaluation can be obtained near exactly by using numeric integration / simulation code, but evaluation time is non-linear with dimension. We propose an approach based on Prekopa's LP method for estimating probabilistic contents, which requires the above code only in low dimension. In particular we will investigate the effect of permutations, partial independence and inexactness of evaluation on the global convergence within a bundle method. Furthermore, we will examine the impact on computation time, especially when the problem dimension varies. Finally we will show that in some configurations our approach offers significant advantage over the use of numeric integration code in full dimension.

PROBLEM OF EXPANSION OF AN ELECTRICAL NETWORK WITH RELIABILITY

MILOCA, Simone Aparecida* *UNIOESTE, Brazil*
VOLPI, Neida Maria Patias *UFPR, Brazil*
PINTO, Cleverson Luiz da Silva *COPEL, Brazil*

The problem of planning for power distribution system is complex and is more difficult if the reliability is integrated in the decision of future network planning. This problem can be modeled by operational research techniques, but because of the complexity, the exact techniques are not possible to be applied when the networks considered are real. This work describes the problem considering radial network, where the only energy source is the substation, as well as presents the mathematical formulation and a methodology that permits to integrate the criteria of reliability in the model, based on [1]. The problem consists of determining the capacity, the numbers and the locations of the distribution substations, also the topology in terms of connections of the feeders so that the installation cost and losses are minimized and considers various electrical constraints as Kirchhoff's laws for current and voltage. The problem is formulated as a model of multi-objective mixed integer programming (MIP), which belongs to the class of NP complete problems. The model applies to a primary distribution network of an existing distribution and operating in good condition and they are known to increase the load forecasts of demand for different periods of the planning horizon. Assumes prior knowledge of the branches that can be added to the network, with the options of gauges and definition of nodes connected to the distribution substation. The proposal to use an exact method to solve such a model has been successful when applied to a small network, but proved to be restrictive in the application in real networks due to its size and characteristics of the nonlinear power inherent grids. To overcome this difficulty, it was used a two stage methodology to find good enough solutions for the problem under discussion. The resolution of the model using this methodology adapted to consider reliability in the problem of expansion and the technique presented in the study allowed the creation of multi-stage planning for the expansion of networks for real networks that are larger than those treated by exact methodology.
References: 1. A new power distribution system planning through reliability evaluation technique, S. Bhowmik, S.K. Goswami, P.K. Bhattacherjee, Electric Power Systems Research, 2000.

A STRATEGY OF GLOBAL CONVERGENCE AND CUBIC EXTRAPOLATION TO NONLINEAR PROGRAMMING APPLIED TO OPTIMAL POWER FLOW

PINHEIRO, Ricardo Bento Nogueira* *Universidade Estadual Paulista - UNESP, Brazil*
BALBO, Antonio Roberto *Universidade Estadual Paulista - UNESP, Brazil*
BAPTISTA, Edméa Cássia *Universidade Estadual Paulista - UNESP, Brazil*
NEPOMUCENO, Leonardo *Universidade Estadual Paulista - UNESP, Brazil*

In this work, we present a predictor-corrector primal-dual interior point method with modified logarithmic barrier and cubic extrapolation strategies, to treat exterior (infeasible) points, using global convergence procedure (PCPDMBLGC-EX).. In the definition of the proposed algorithm, the modified logarithmic barrier function method exists and assists in his boot with infeasible points that belong to the relaxed infeasibility region (expanded). However, the infeasibility can occur at points that are not near the relaxed border or not belong to this region, thus implying the inexistence of the modified logarithmic barrier function. To overcome this difficulty, is applied to a cubic extrapolation that preserves the first and second order differentials near the border; in the predictor procedure are carried out updates the barrier parameter in the complementarity constraints residues, considering first order approximations of the search direction system, whereas in the corrector procedure, the nonlinear (quadratic terms) residues, that had been unvalued in the procedure predictor, are included. We also consider the global convergence strategy for the method, which uses a variant of the Levenberg-Marquardt's method to update the dual normal matrix of Lagrangian function, if it is not positive definite. In this case, this matrix is extended to equality and inequality primal constraints with bounded variables. An implementation of this method, performed in Matlab 6.1, was effective when applied to OPF problems, located in the Electric Power System (EPS) area, in Electrical Engineering, whose objective function and the constraints set are nonlinear and nonconvex functions. We give highlight to the results of method application in the electrical system IEEE-162, comparing them with others already published.

A PORTFOLIO OPTIMIZATION MODEL FOR RENEWABLE ENERGY TRADING

BRUNO, Sergio Vitor de Barros* *Petrobras, Brazil*
STREET, Alexandre *PUC-Rio, Brazil*

The Brazilian energy market has been experiencing some changes in the last years. After decades of a dominant hydroelectric setup, the energy matrix was complemented by thermoelectric plants. More recently, renewable sources have been gaining projection, especially because of government auctions. These sources can be divided into small scale hydro plants, which have small or no storage capacity, biomass cogeneration from sugarcane waste and wind power generation. These auctions are designed as to encourage renewables participation, providing rules that account for the variability of the energy offer due to seasonal constraints. Still, renewables share of the unregulated (free) market is very small, since the uncertainty of its generation is reflected on its commercial feasibility. Recent studies have shown that the seasonality of those sources is complementary, allowing trading companies to negotiate contracts backed on the combined sources. The composed availability allows greater pricing due to reduced volatility in generation, thus creating value. In this work we propose a framework for optimizing the participation in a portfolio of several renewable sources, from a trader perspective. We introduce a multi-stage stochastic programming model with risk aversion that coherently mitigates the underlying risks. Numerical results are presented to illustrate the benefits of the method.

ENHANCING THE PERFORMANCE OF THE POWER MONITORING CHANNELS IN NUCLEAR REACTORS

MESQUITA, Amir Zacarias *Centro de Desenvolvimento da Tecnologia Nuclear (CDTN), Brazil*
REZENDE, Hugo Cezar *Centro de Desenvolvimento da Tecnologia Nuclear (CDTN),*
SANTOS, André Augusto Campagnole dos *Comissão Nacional de Energia Nuclear (CNEN),*
PALMA, Daniel Arthur Pinheiro ,

Power monitoring channels play a major role in retaining a safe reliable operation of nuclear reactors. Accurate power monitoring using advanced developed channels could make nuclear reactors a more reliable energy source and change public mind about this major energy resource. The recent accidents in Fukushima reactors and its effects on the environment show the importance of developing new safety system. Two important criteria for power measurement in nuclear reactors are redundancy and diversity. Other criteria such as accuracy, reliability and speed in response are also of major concern. Power monitoring of nuclear reactors is always done by means of neutronic instruments, i.e. by the measurement of neutron flux. The greater the number of channels for measuring power, the greater is the reliability and safety of reactor operations. The aim of this research is to develop new methodologies for on-line monitoring of nuclear reactor power using other reliable processes. One method uses the temperature difference between an instrumented fuel element and the pool water below the reactor core. Another method consists of the steady-state energy balance of the primary and secondary reactor cooling loops. A further method is by calorimetric procedure whereby the reactor power is monitored as a function of the temperature-rise rate and the system heat capacity constant. Another methodology, which does not employ thermal methods, is based on measurement of Cherenkov radiation produced within and around the core. The first two procedures, fuel temperature and energy balance, were implemented in the IPR-R1 TRIGA nuclear research reactor at Belo Horizonte (Brazil) and are the focus of the work described here. Knowledge of the reactor thermal power is very important for precise neutron flux and fuel element burnup calculations. The burnup is linearly dependent on the reactor thermal power and its accuracy is important in the determination of the mass of burned 235U, fission products, fuel element activity, decay heat power generation and radiotoxicity. The thermal balance method developed in this project is now the standard methodology used for IPR-R1 TRIGA reactor power calibration and measuring power by using the fuel temperature is the most reliable way of on-line monitoring of this reactor power. This research project primarily aims at increasing the reliability and safety of nuclear reactors using alternative methods for monitoring their power.

MODELING AND EVALUATION POWER DISTRIBUTION NETWORK CONSIDERING THE APPLICATION OF SMART GRIDS

SCHREIBER, Jonas Fernando* *UNIJUI-Universidade Regional do Noroeste do Estado do RS, Brazil*
SAUSEN, Paulo *UNIJUI-Universidade Regional do Noroeste do Estado do RS, Brazil*
SAUSEN, Airam *UNIJUI-Universidade Regional do Noroeste do Estado do RS, Brazil*
CAMPOS, Mauricio *UNIJUI-Universidade Regional do Noroeste do Estado do RS, Brazil*

This paper discusses the proposal for an analytical study of the mathematical models aiming to use electrical power lines for the data transmission. With technological advances, especially with the researchs on smart grids and smart metering, the traditional models now need to represent other signs beyond the electrical signal, for example, Power Line Communication (PLC). In this study we used two simulation platforms: a computational and an emulator on power reduced scale of an electric network built especially for this purpose. In this context, this paper is focused on the mathematical computer model of a part of an electric power network, evaluating their performance in terms of electrical representation, as well the transmission of the communication signal at high frequency. The PLC is an excellent solution because uses the conventional energy grids, no need for new transmission lines, sending by the same channel the electrical signal and data, with difference in frequency range. The mathematical model most used in computer representation of power line is known as PI model. Initially was chosen to work in MATLAB / Simulink. As the main objective of this evaluation is the monitoring of data flow through narrow-band circuits, it was necessary to adapt the Communication Blockset Simulink to allow the simulation of the power line by transfer function, considering the complete PI circuit. As a continuation of this research will be presented results showing that this mathematical model does not represent the best way of network power grid, being proposed a better model.

GIVMP: A HYBRID HEURISTIC ALGORITHM FOR SOLVING THE UNRELATED PARALLEL MACHINE SCHEDULING PROBLEM WITH SEQUENCE DEPENDENT SETUP TIMES

HADDAD, Matheus Nohra* *Universidade Federal de Ouro Preto, Brazil*
SOUZA, Marcone Jamilson Freitas *Univesidade Federal de Ouro Preto, Brazil*
MARTINS, Alexandre Xavier *Univesidade Federal de Ouro Preto, Brazil*

This work addresses the Unrelated Parallel Machine Scheduling Problem with Sequence Dependent Setup Times, or just UPMSP. In this problem there is a set of jobs and machines and for each job there is a processing time associated, which is different for each machine. Given two jobs, there is also a setup time that depends on their sequence and on the machine used. The objective considered in this problem was to minimize the maximum completion time of the schedule, the so-called makespan. The UPMSP is often found in industries and belongs to the NP-hard class. Aiming to its resolution, it is proposed a hybrid heuristic algorithm, named GIVMP. This algorithm combines the heuristic procedures Greedy Randomized Adaptive Search Procedure (GRASP), Iterated Local Search (ILS), Variable Neighborhood Descent (VND), Path relinking (PR) and a Mixed-Integer Programming model (MIP) used to solve the Asymmetric Travelling Salesman problem. To explore the solution space, insertion and swap movements between machines are used. In order to test the algorithm, two sets of test problems from the literature are used. Then, this algorithm was compared with six other in literature, being two in the first set of test problems and four others in the second. In the first set it was found the superiority of GIVMP on two genetic algorithms of the literature, having been found lower relative percentage deviations and new best solutions. In the second set of test problems it was showed that the performance of GIVMP is lower than one of the algorithms, but higher than the other three. It is observed, however, that in this second set of problems, the average relative percentage deviations of the algorithms were not available, but only the deviations of the best values found, which impedes a comparison of robustness of the algorithms.

AN INVESTIGATION ABOUT BARRIER PARAMETERS UPDATE STRATEGY AND OPTIMAL POWER FLOW SOLUTION

FERREIRA, Ellen Cristina* *São Paulo State University "Júlio de Mesquita Filho" - Unesp Bauru, Brazil*
BAPTISTA, Edméa Cássia *São Paulo State University "Júlio de Mesquita Filho" - Unesp Bauru, Brazil*
SOLER, Edilaine Martins *São Paulo State University "Júlio de Mesquita Filho" - Unesp Bauru, Brazil*

In Electrical Power Systems, an area of study in Electrical Engineering, Optimal Power Flow (OPF) consists of a large-scale constrained, nonlinear, nonconvex optimization problem which seeks the best operating

point of the Electrical System, optimizing an objective function and satisfying its operating constraints, a characteristic that serves as a support tool for engineers of electric power companies. The OPF problem was proposed by Carpentier in the early 1960s, based on the economic dispatch (ED) problem, by adding power flow equations to the ED model. ED is used by electric power distribution concessionaires to determine how much power each generating unit should produce to meet the system's total demand at the lowest cost. Due to their efficiency in solving linear and nonlinear programming problems and their easy implementation, interior point methods became an alternative for many applications, including OPF problem. These methods use differentes strategies for updating the barrier parameter. In this work we propose investigate the influence of these strategies in the solution of the OPF problem, when we used an interior point method. For this investigation were chosen the Knitro, a package for nonlinear optimization. In its implementation of the interior point method, the Knitro replaces the nonlinear programming problem by a sequence of subproblems barrier for a controlled parameter barrier. The algorithm uses trust regions and a merit function to promote convergence, performs one or more minimization steps on each barrier subproblem decreases the barrier parameter, and repeats the process until the original problem is solved with the desired precision. In the package Knitro six strategies are available for update the barrier parameter: (i) the barrier parameter is decreased monotonically, (ii) the barrier parameter is calculated by an adaptive rule based on the complementarity gap, (iii) is carried out an investigation about step (affine-scaling) to dynamically determine the barrier parameter value at each iteration, (iv) is used a Mehrotra predictor-corrector type rule to determine the barrier parameter taking into account the corrector step, (v) is used a Mehrotra predictor-corrector type rule to determine the barrier parameter without considering the corrector step, and (vi) a merit function is minimized at each iteration to determine the barrier parameter. These strategies are used in this work for verification of your influence in the OPF.

OPTIMIZED CABLE SELECTION FOR OVERHEAD TRANSMISSION LINES

DAMBISKI, Leandro Prevedello* *UTFPR and COPEL, Brazil*
ARRUDA, Lúcia Valéria Ramos de *UTFPR, Brazil*
NEVES JUNIOR, Flávio *UTFPR, Brazil*

In present days overhead transmission lines are still the most used method for power transmission, mainly because its relative low cost and high efficiency. That's the reason why optimization for transmission lines is one issue of interest for all electrical energy companies. The definition of the optimum conductor in a transmission line depends on many variables such as: line length, voltage, loading requirements, power quality constraints, electrical line parameters, installation and system losses costs, and environmental conditions, mainly winds and extreme temperatures. It's known that usually the conductor's feature of more interest for the projects is its thermal limits. The conductor represents about 40% of the total capital costs of the transmission line, considering material and installation costs. It also has great influence in cost of system losses. These two economic factors are very critical while selecting the best conductor for an overhead line as we look trough the operation costs over 30 to 50 years. In most of cases, the conductor selection is made in the same range of conductors because conductors are patterns used by the fabricators. This range includes cables from the types Aluminum Conductor Steel Reinforced, Ibis cable for instance, and Aluminum Conductor Extra-High-Strength Steel Reinforced, Petrel cable for instance. But continuous change in the cost of material of conductor and new manufacturing technologies make the conductor selection a complicated and dynamic task. This paper presents a new and improved methodology for optimizing conductor for overhead transmission lines, by using the optimization software Lingo 8.0. This study will guide planers towards least cost solutions regarding conductors. There are many constraints in the model, like power quality constraints and conductor thermal limits. The main parameters of the optimization model are the project criteria like voltage and line length. As we change the entering parameters, we can see big difference in the results, as different conductors are indicated according to minimal changes in project criteria. About 50 simulations were made in order to select the least expensive cable solution for transmission lines and compare then. The results and comparative studies provide helpful information for line transmission planers from many regions in the world, since the studies of this paper are very generic ones.

RANGE OPTIMIZATION OF HYBRID VEHICLES

GRANATO, Giovanni* *Ensta ParisTech - INRIA Saclay - Renault SAS, France*

This study proposes an algorithm to synthesize controllers for the power management of hybrid vehicles that maximizes the vehicle range along a given route. The algorithm stems from a level-set approach that computes the reachable set of the system via the computation of the value function of an optimal control problem. The discrete-time vehicle model is one of a particular class of hybrid vehicles, namely, range extender electric vehicles (REEV). This kind of hybridization departures from an full electric vehicle that has an additional module -- the range extender (RE) -- as an extra source of energy in addition to its main source of energy -- a high voltage battery. As an important feature, our model allows for the switching on and off of the range extender and includes a decision lag constraint, i.e., imposes two consecutive switches to be separated by a positive time interval. The approach consists in the introduction of on adequate hybrid optimal control problem with delay constraints on the switch control whose value function allows a characterization of the reachable set. The value function is in turn characterized by a dynamic programming algorithm. This algorithm is implemented and some numerical examples are presented. This work is motivated by an application in the automobile industry, namely, calculating the autonomy of a class of electric vehicles (EVs), namely, range extender electric vehicles (REEV), which posses two distinct sources of energy from which we can use to tract the vehicle. In this setting, the study aims at finding the control sequence of the two energy sources that allows the vehicle the reach the furthest possible point of a given route, optimizing thus the vehicle autonomy. The REEV is modeled as a discrete-time hybrid dynamical system in which the state vector represents the energy capacities of the two different energy sources embedded in the vehicle. The controls of the vehicle includes the power split between the two energy sources and the state of the range (on or off) of the range extender. The model also considers a decision lag constraint in the switch control, meaning that a period of time is imposed between two consecutive switches. A reachable set is defined and we use a classic level-set approach, characterizing it via the resolution of an optimal control problem. In this work, we present some results using a toy model and a more realistic vehicle model.

AN INTEGRATION OF OPTIMUM ELECTRIC DRIVE CONTROL SYSTEMS WITH DOWNSIZED ICE TO BUILD AN EFFICIENT PARALLEL HYBRID VEHICLE ARCHITECTURE

RAMDASI, Sushil Shrikrishna* *ARAI / VIT, India*
SENTHILKUMAR, A *VIT, India*
THIPSE, Sukrut S *ARAI, India*
MARATHE, Neelkanth V *ARAI, India*

Sustainable mobility leading towards cleaner environment while addressing depletion of fossil fuel issue is imposing a revolutionary change in shifting from conventional power train technology to the mix of many engineering disciplines under one roof. This need along with coming stringent norms has already started trend towards extreme downsizing and down speeding of I.C. Engines in the range of 65-80 kW/lit resulting in reduction of CO2 up to 120 g/km.In order to go beyond further than present fuel economy and CO2 emission landmarks achieved, one of the most promising technology emerging out is Hybrid Electric Vehicle. This paper depicts a systematic approach followed to build parallel Hybrid electric vehicle architecture suitable for a passenger car vehicle equipped with 1.3 lit downsized diesel engine with 5 speed manual transmission. After study of various architectures possible viz. mild, series, parallel and complex, parallel hybrid configuration is selected to begin with. Base vehicle performance in terms of chassis dynamometer cycle level emissions, fuel consumption along with acceleration levels in different gears and max velocity achieved is simulated using CRUISE algorithm. The simulated performance is compared with the tested vehicle performance. The calibrated model is used as a base for designing various control strategies for electrification. Complete optimization is done on EUDC, since base vehicle performance is validated on the same. Fuel economy of 2.77l / 100 km against 4.83 / 100 km while CO2 emissions have come down to 71.2 gm/km from 124.2 gm / km which is a substantial reduction with the extent of electrification. Apart from emission as a goal, electrification is used a booster to improve acceleration performance in all gears. By taking Torque vs. speed operating points on different cycles as a duty cycle, motor characterization along with inverter switching frequency look up tables is worked out. Direct Torque Control and Field Oriented Control strategies with the help of MATLAB/ SIMULINK simulations are worked out to improve transient behavior of motor thus improving power factor. Developed control strategies are experimentally evaluated on scaled down performance motor and Microautobox for its transient behaviors. Thus an integration of electric drive control system with downsized ICE is worked out to build an optimum and efficient parallel hybrid vehicle architecture with minimum cost implications.

PLANNING FOR A DISTRIBUTION SYSTEM CONSIDERING LOAD FORECASTING AND INSERTING A NEW POINT OF SUPPLY AT MEDIUM VOLTAGE

ALZENIRA, da Rosa Abaide *Federal University of Santa Maria, Brazil*
MOISÉS, Machado Santos *Northwest Regional University of Rio Grande do Sul (UNIJUI), Brazil*
SANDRO, Alberto Bock *City Department of Energy in Ijuí (DEMEI), Brazil*
LUCIANO, Malaquias *Federal University of Santa Maria, Brazil*
LUCIANE, Neves Canha *Federal University of Santa Maria, Brazil*
TAFAREL, Franco Milke* *Federal University of Santa Maria, Brazil*

The regulatory framework since the mid-90s, the Brazilian electric sector went through a restructuring process, where the rules were established that defined its operation, since the generation activity, including the transmission, distribution, to marketing energy. With this, the Brazilian electric system took large proportions, greatly increasing its complexity, especially when it comes to quality, reliability and operation. Thus, the main objective of the electricity sector has become the commitment of security of supply, quality and low tariffs, which is a fair price in return for providing an adequate service for the supply of electricity. In this new model, the electricity has become a key product for the development of humanity, enabling an improved quality of life through technological innovations that promoted the modernization of society. This paper presents a case study about the planned expansion of the distribution system of a medium voltage distribution utility in the region south of the country. The main objective is to find the most appropriate reconfiguration for this system in order to meet the demands of future loads with quality and reliability. The task is to model and diagnose the system loads, proposing a new configuration considering only point in the new medium voltage supply for this system. With the acquisition of real data measurements of the feeders, it was possible to perform simulations for normal operation and contingency, for each planning horizon. Planning studies are aimed at achieving desired future states, efficiently and effectively. In this case study, there was first the modeling of the distribution system with the current charges, dividing loads into blocks, which were analyzed more easily. Applying the annual vegetative growth of load in the respective blocks, through the statistical approach of the direct method of regression analysis, we carried out the study of load growth considering the historical consolidated consumption of the last five years. Through an algorithm developed in MATLAB® platform, we had the result percentage for each horizon. Through simulation software PTW (Power Tools For Windows) has been installed its distribution network with its blocks simulated for each horizon. The application software provided the data system and the percentage of load growth, therefore, we sought the best possible configuration for this system.

DIRECT DETERMINATION OF MAXIMUM LOADABILITY POWER FLOW SOLUTIONS THROUGH A TRUST REGION BASED OPTIMIZATION METHOD

SALGADO, Roberto de Souza *Federal University of Santa Catarina, Brazil*
MORAES, Guido Rossetto* *Federal University of Santa Catarina, Brazil*

Because of the considerable degree of difficulty of the convergence of the numerical methods used in the power system analysis, new methodologies have been proposed to increase the numerical robustness of the iterative process. Previous application of trust-region based algorithms in Power System State Estimation and Optimal Power Flow present a number of advantages [1,2]. This paper proposes the direct determination of the power flow solution at the critical loadability point. This is formulated as a constrained static optimization problem, similar to that shown in [3] , which is solved by a trust-region based optimization method. The power flow equations are expressed in rectangular coordinates, which allows to use of the second-order (tensor) term of the Taylor series expansion of the power flow equations. It is shown how relations of sensitivity at the point of critical load can be obtained as a by-product of the optimization method and used to determine preventive or corrective measures. Numerical results obtained for power systems with sizes ranging from 6 to 750 buses and thousands of variables are used to illustrate the features of the proposed methodology.
References [1] A. Simões Costa, R. S. Salgado, P. Haas, Globally Convergent State Estimation Based on Givens Rotations, IREP Symposium 2007, Bulk Power System Dynamics and Control VII, Charleston, South Carolina, USA . [2] A. A. Sousa, G. Torres, Globally Convergent Optimal Power Flow by Trust Region Interior Point Methods, Vol. I, Lausanne-Switzerland, 2007. [3] R. S. Salgado, A. F. Zeitune, A direct method to determine the maximum loadability bifurcation point in electric power systems, in: 2nd International Conference on Engineering Optimization, Lisbon, Portugal, 2010.

OPTIMAL ALLOCATION OF CAPACITOR BANKS CONSIDERING THE IMPACT OF DISTRIBUTED GENERATION

DOS SANTOS, L. L. C. *Northwest Regional University of Rio Grande do Sul, Brazil*
SANTOS, M. M. *Northwest Regional University of Rio Grande do Sul, Brazil*
ABAIDE, A. R. *Federal University of Santa Maria, Brazil*
MILKE*, T. F. *Federal University of Santa Maria, Brazil*
MALAQUIAS , L. *Federal University of Santa Maria, Brazil*

In recent decades, there has been a growing interest in distributed generation, in many countries, driven mainly by the concept of sustainable development. There are several technologies that incorporate the concept of distributed generation (DG), such as generation based on biomass, solar, wind and through small hydropower plants (SHP). There are several reasons for the increasing use of GDs in the systems world, among which are: The reduction of environmental impacts; The use of fuels available close to load centers such as NG (natural gas), hydrogen (H2), alcohol (ethanol) and so on.; Equipment with different powers available, allowing customers with scalable from small single units to large consumer groups through clustering of generators forming “small plants” close to the load; Costs of generation and transmission of electricity competitive with alternatives that reduce at the same time maintaining the service to end users within the highest levels accepted and allowed by regulatory agencies. In literature, there are queries related to the impact of DG on the stability, voltage control, power losses, power quality and its potential to provide ancillary services. Are presented in a series of indices to assess the impact of DG in distribution networks, these indices include: active and reactive losses, voltage level, reserve capacity in the feeders and short circuit currents. In this paper, the objective is to contribute to studies on the impact of DG on distribution systems to analyze the effect of distributed generation in the allocation of capacitor banks. Normally, the power injected by a distributed generator helps to improve the voltage profile and/or have a positive impact in reducing losses on the other hand reduces the power factor at the point of connection and supply distributors. The problem can be solved by determining the optimal location and sizing of capacitor bank, the scenarios in which the existence of multiple DG units connected to the utility network. The methodology proposed in this paper is the use of genetic algorithms. In solving the problem of power flow, we used the fast decoupled method with rotation axes. This approach allows the utility to evaluate the impact that the inclusion of DG in voltage levels, system losses, especially in the power factor. Throughout his work, we present simulations and tests using real data feeds, as well as small hydropower plants (SHP) connected to the system.

GPU and parallel processing.

PARALLEL COMPUTATION OF ADJOINT DESIGN SENSITIVITY FOR NANO-CONTINUUM MULTISCALE MOLECULAR DYNAMICS

JANG, Hong-Lae* *Seoul National University, Korea*
KIM, Jae-Hyun *Seoul National University, Korea*
PARK, Youmie *Inje University, Korea*
CHO, Seonho *Seoul National University, Korea*

Recently, nanotechnology is one of the emerging research fields to describe the modern engineering problems such as nanoscale sensors, ultra-strength materials, drug delivery design, and so on. Therefore, it is naturally increasing to consider microscopic level in design. The molecular dynamics (MD) simulation that predicts the microscopic behaviors of materials is a promising tool to describe complex physical phenomena. However, a huge amount of computation is required for the transient dynamic analysis in atomic based simulations. When it comes to the field of design optimization, finite difference sensitivity for the transient dynamics is computationally costly but too inaccurate to be used in the design optimization. Many researchers developed the algorithms of MD simulations in parallel computing environment. Plimpton presented the parallel algorithms for short-range molecular dynamics. Even though the MD is performed in parallel computing environment, there still remain some problems for the DSA of MD simulation. The approximated DSA methods such as finite difference method are impractical from the viewpoint of sensitivity efficiency and accuracy since the MD may include so many highly nonlinear design parameters. Hence, an efficient analytical DSA method is indispensable for the design optimization by the MD. The adjoint variable method for the transient dynamics was well established and the corresponding adjoint system turned out to be a terminal value problem. Extension of design sensitivity analysis methods to the atomic level transient dynamics was never tried due to the limitation of computational resources and lack of efficient DSA method even though the MD is already established. In this research, we present the adjoint DSA method for the MD in parallel computing framework. For the computational efficiency, the parallel computing based spatial decomposition method is performed in both analysis and DSA stages. The domain is decomposed with spatial boxes along the positions of atoms. To compute the interaction forces between atoms in different spatial boxes, only the known positions of atoms in nearby boxes are required. Through some numerical examples, the accuracy and efficiency of the derived adjoint design sensitivity are compared with the finite difference one.

ELECTRICAL IMPEDANCE TOMOGRAPHY IMAGE RECONSTRUCTION THROUGH SIMULATED ANNEALING USING GPU PARALLELIZATION AND OUTSIDE-IN HEURISTIC

TAVARES, Renato Seiji* *Escola Politécnia da USP, Brazil*
TSUZUKI, Marcos de Sales Guerra *Escola Politécnia da USP, Brazil*
MARTINS, Thiago de Castro *Escola Politécnia da USP, Brazil*

Electrical Impedance Tomography (EIT) is a medical imaging technique that estimates electrical conductance distribution of part of the subject's body. The conductance distribution can be estimated by applying alternating low amplitude current through conducting electrodes on the subject's surface and measuring electrical potentials. Alternatively, electrical potentials can be applied through the electrodes and the

currents are measured. The process is repeated for numerous different configurations of applied current. EIT inverse problem is ill-posed, a characteristic that makes it highly dependent on the reconstructing algorithm used. Its resolution may be formulated as an optimization problem, which can be solved using simulated annealing. Simulated annealing is one of the techniques that is able to obtain absolute images, and it is being reported in the literature to be able to obtain more than satisfying results. However, although the commonly used objective function, which forces the minimization of the difference between the measured potential and the estimated potentials, is able to reconstruct the body's conductance distribution properly, results come at a very high computational cost. The necessity of evaluating the objective function in every single iteration requires the solving of the whole ill-posed non-linear system, through innumerous matrices-vectors operations that are part of the conjugate gradient method and the preconditioner calculation. The parallelization of such operations, using GPU programming, is able to accelerate the solving of the system and reduce the total computing time. As last, as the electrodes are located on the surface of the subject, where either the current or the electrical potential is applied and the all measures are taken, the surface possess more reliable data and is more sensitive to the random disturbances made by the simulated annealing algorithm. As a result, it enters the refining phase before the inner region of the subject. Such behavior can be amplified using an "outside-in" heuristic.

DEVELOPMENT AND IMPLEMENTATION OF PARALLEL VERSIONS OF THE PARTICLE SWARM ALGORITHM ON CLUSTERS USING MPI

MORAES, Antonio de O Samel* *PEQ/COPPE/UFRJ, Brazil*
LAGE, Paulo Laranjeira da Cunha *PEQ/COPPE/UFRJ, Brazil*
SECCHI, Argimiro R. *PEQ/COPPE/UFRJ, Brazil*

In despite its recognized strenght in global optimization problems, the high number of objective function evaluations requested by Particle Swarm Optimization (PSO) method severely limits its aplication when the computational cost of the objective function calculation is large, as in most real engineering problems. In order to overcome this deficiency, enabling the efficient use of the PSO algorithm in the large-scale engineering problems, the parallel computation in clusters appears as an excellent alternative for reducing the optimization time. By its nature, this algorithm can be easily parallelized, because the objective function is calculated independently for each particle in the swarm. Therefore, three parallel versions of the PSO algorithm, using the set of functions of the MPI (Message Passing Interface) library, were developed in this work. These parallel algorithms use the master-slave paradigm to exchange information between the processors, differing among themselves by the communication mode among the master and the slave processors (synchronous or asynchronous) and the particles update in swarm (immediate or by swarm). A set of benchmark tests was conducted to validate and to analyze the perfomance of the developed methods. In particular, the AIUPPSO algorithm (Asynchronous and Immediate Update Parallel PSO) showed excelent perfomance, with linear speed-up and parallel eficiency higher than 90 % for all problems tested. The results were obtained in the MIMD parallel computers with distributed memory and Infiniband network of the cluster in the Termofluidynamics laboratory (LTFD of PEQ/COPPE/UFRJ). Finally, an actual parameter estimation problem with a costly objective function was solved and the solution was compared to that provided by the ODRPACK95 optimizer.

CONJUGATE GRADIENTS IMPLEMENTATION ON A TESLA GPU: A TOOL FOR FAST HYPERSPECTRAL SENSOR SIGNAL OPTIMIZATION

PONCE, Eduardo *ORNL, United States of America*
IMAM, Neena *ORNL, United States of America*
BARHEN, Jacob* *ORNL, United States of America*

A critical stage in missile defense involves negating ballistic missiles equipped with multiple warheads and decoys during the midcourse attack phase, by means of a single engaging interceptor missile carrying a multiple-kill-vehicle payload. For an accurate spectral assessment of a target kill, flash radiometry such as provided by the CTIS sensor, is required. CTIS employs diffractive optics and computer generated holograms to project a target's image onto a focal plane array (FPA) without involving any scanning functions, and therefore introduces no time-related artificial distortions to the phenomenon being spectrally analyzed. One of the major challenges of this technology is that CTIS does not measure a target signature directly, but in a manner that requires complicated and time-consuming post-processing. Previously, statistical algorithms

(e.g., MEM - mixed expectation maximization) have been used for target acquisition from FPA data. Typical reported timings per "reconstructed" target exceed several minutes per frame for targets and FPAs of size relevant to MDA applications. Hence, there is a strong rationale to provide fast algorithms and tailor them to novel computational hardware that would enable real-time performance. In particular, there is a need to achieve target image reconstruction in less than 10 ms, which would require a speedup factor in excess of 10,000. To meet this goal, we have previously reported the development of several algorithms including terminal (i.e., non-Lipschitzian) attractor dynamics, and sparse conjugate gradient (SCG). All were considerably faster than MEM, but the latter was shown to exhibit a speed-up factor close to 1000. In this paper, we report the implementation of our SCG algorithm on a fast multicore computational platform, the NVIDIA Tesla C2050GPU. CG typically deals with a square, symmetric, positive definite matrix A. This is not the case for the CTIS optical transfer matrix H. The conventional approach of considering the associated normal equations is unsustainable: while H is sparse, HT H would be dense. Here, we fully exploit the sparsity of H, albeit at the cost of an additional matrix-vector (sparse) multiplication per iteration. High-performance and increase in speedups are obtained from efficient use of GPU resources such as vector and matrix representations, coalesced memory accesses, load balancing, and asynchronous calls.

LC-SVM : A SUPPORT VECTOR MACHINE WITH UNEQUAL MISCLASSIFICATION COSTS

CAPITANI, Leandro M.* *ITA - Aeronautics Institute of Technology*, *Brazil*
SCARPEL, Rodrigo A. *ITA - Aeronautics Institute of Technology*, *Brazil*
AZEVEDO, Erica M. *Unicamp - State University of Campinas*, *Brazil*

Since its creation, SVM has been a fundamental piece in applications through several areas of knowledge and also focus of theoretical studies which generated a few variants: Least Squares Support Vector Machine (LS-SVM), 1-norm-Support Vector Machine (1-norm-SVM), Proximal Support Vector Machine (PSVM) and Knowledge based Proximal Support Vector Machine (KBPSVM); all of them intending to optimize some characteristic or mitigate the original formulation limitations. We propose the LC-SVM, a variant of the original formulation that allows unequal misclassification costs. The new model incorporates characteristics of integer programming, but it still minimizes not only the empiric risk but also the structural risk. The modifications made on the objective function and on the constraints do not alter the generalization ability of the SVM, maximizing the margin separating hyperplane. Due to the nonlinear characteristics of the restrictions it was opted, arbitrarily, to use an evolutional method (evolutionary strategy) to find a solution. We show that by varying the misclassification penalizations the solution privileges one class against the other, as expected.

Industrial Applications

SOLVING UNIFORM COVERAGE PROBLEMS IN INDUSTRIAL PRODUCTION WITH ABEL INVERSION

NOWAK, Dimitri* *Fraunhofer Institute for Industrial Mathematics (ITWM), Germany*
KÜFER, Karl-Heinz *Fraunhofer Institute for Industrial Mathematics (ITWM), Germany*

The homogeneous deposition of material on complex surfaces, e.g., powder coating, paint spraying, fiber lay-down etc., is a well-known task in industrial production. This talk introduces a mathematical model for a typical process class of such uniform coverage problems motivated by the spunbond process. The process class is characterized as follows: assume that a bar rotates around a center with uniform speed and specified constant mass distribution along the bar. Simultaneously, the center of the bar is moved in some direction along the surface with constant speed. By the superposition of rotational and translational movements, a pattern is generated. In optimization, it is natural to aim for a modification of mass distribution in relation to rotational and translational speed such that the surface is covered as homogeneously as possible. We show that coverage patterns can be approximated accurately by means of radial basis functions. The use of radial basis function reformulates the originally two-dimensional coverage problem into a one-dimensional one. In consideration of Abel Inversion, we obtain a space of intuitively desirable exact solutions. The talk is organized as follows: After an introduction of the problem and a description of the mathematical model in the first part, a thorough mathematical analysis is provided in the second part. In particular, the role of model reduction is discussed. In the last part, numerical results illustrate the benefit of the new approach, specifically, its approximative behavior.

IMPROVEMENT ON THE ARRANGEMENT OF THERMOCOUPLES TO ESTIMATE THE WEAR LINE OF A BLAST FURNACE HEARTH

MAGNAGO, Luiz Claudio Silva* *Universidade Federal do Espírito Santo, Brazil*
CATABRIGA, Lucia *Universidade Federal do Espírito Santo, Brazil*

A model for estimate the wear line in a blast furnace hearth is presented. Since the hearth is one of the most critical parts in determining the campaign length of a blast furnace, it is very important to monitor this wear line, in order to schedule the hearth relining at the right time. In case of a late relining there is a security risk, and in case of an early relining, there is an unnecessary loss of capital. We present a model for estimate the 1150ºC isotherm, which represents a potential limit on the penetration of liquid iron into the hearth wall porosity, being regarded as the isotherm that represents the wear line position. The procedure is based on the solution of a non-linear inverse heat transfer problem where the observations are temperature measurements made with thermocouples and the unknown is the location of the 1150ºC isotherm. Like most inverse problems, the estimation of the 1150ºC isotherm is mathematically classified as ill-posed, because the solution may become unstable, as a result of the errors inherent to the measurements done by the thermocouples. Depending on the arrangement of the thermocouples used, the solution of the inverse problem can become more sensitive to measurement errors in the input data. In this work, we solved the inverse problem to estimate the wear line on a hearth with similar characteristics of the Blast Furnace 3, installed at the Arcelor Mittal Tubarão. The method used to solve the inverse problem is the Levenberg-Marquardt method. The finite element method was used to solve the direct problem. The direct problem presents a non-linearity, due to the themal conductivity of the refractory walls of the hearth are temperature-dependent, that was solved with the fixed point iteration. The solution was validated using simulated measurements with different noise levels. We compared different arrangements of thermocouples in order to find a better position than the one found at the Blast Furnace 3.

INVERSE COMPUTATION SCHEME OF TURBOMACHINERY BLADE SHAPES APPLIED TO AXIAL HYDRO-TURBINE RUNNERS

SANTOS, Marcos Antonio Rodrigues dos* *Federal University of Itajubá, Brazil*
MANZANARES-FILHO, Nelson *Federal University of Itajubá, Brazil*
OLIVEIRA, Waldir de *Federal University of Itajubá, Brazil*
SANTOS, Luís Guilherme Cunha *Federal University of Itajubá, Brazil*

In this work an inverse scheme is proposed for computing the mean through flow surface of turbomachinery. The flow is considered inviscid and incompressible with the blades supposed infitely thin. The computational domain consists of a meridional projection extending from the upstream section to the downstream section. Averaging the continuity and momentum equations leads to an equivalent elliptical differential equation for the stream function which is complemented by (i) the conservation of hydraulic torque condition along streamlines for the bladeless regions and (ii) the mean flow tangency condition for the bade region. The blade region may be treated in direct mode solving for the stream function and hydraulic torque with a prescribed blade shape. For design purposes one adopts here an inverse approach by solving for the stream function and blade shape with a given hydraulic torque distribution. The stream function equation is solved iteratively by a differential quadrature method with SOR (Successive Over-Relaxation) using a non-orthogonal mesh. The projections of the blade leading and trailing edges coincid with mesh knots. An application is made for designing the conceptual mean runner blade surface of an axial flow hydro-turbine.

METHOD FOR DETECTING HIGH IMPEDANCE FAULTS WITH PARAMETER IDENTIFICATION BY VOLTAGE SUPERPOSITION

KETZER, Marcos Batista* *Universidade Federal de Campina Grande, Brazil*
JACOBINA, Cursino Brandão *Universidade Federal de Campina Grande, Brazil*
CAMPOS, Mauricio *Universidade Regional do Noroeste do Estado do Rio Grande do Sul, Brazil*

Introduction: Most of the Brazilian electric power circuit belong to system distribution, what is the most prone to faults due to their physical characteristics and occupancy. To detect such faults, the magnitude of current or voltage that are common criteria for the development of protective systems are partially effective. The faults that are not detected by these methods due to a small energy drain from network compared to the loads connected to it, have been studied and have particular solutions, which have not been successfully generalized. These are called high impedance faults. This paper presents the study of a new algorithm that is based on injection of voltage signals of zero sequence at a frequency greater than the fundamental of the operating system, superimposed on it. The technique developed utilizes stochastic methods, and, more precisely, a parameters identification algorithm. Also, the algorithm in question allows the detection of faults arising from elements with linear and nonlinear dynamics. Materials and methods: Whereas the synthesis of impedance is linear, the resulting zero sequence estimation has an inductive and a resistive component. For the identification of the event, it is observed the rate of variation of identified parameters and covariance matrix of the estimator. The base case for each parameter variation is made upon an initial case, which considers the normal system operation. The logic developed allows detect other cases of change of the network, such as addition of load or capacitor bank, in a different way, thus allowing the update of the basic parameters. Furthermore, the algorithm is in a recursive form, making it more appropriate for real time applications. This methodology is validated in a distribution system operated by the Departamento Municipal de Energia Elétrica de Ijuí, located in Rio Grande do Sul, Brazil. Results: To validate the algorithm developed are created events with linear and nonlinear faults, with different magnitudes and location in reference to the feeder. Are also validated cases of connection of capacitor banks and asymmetric loads. The proposed detection algorithm correctly detected the occurrence of events, as well as their classification.

A MULTICRITERIA CONFIABILITY METHODOLOGY WHITH THE ADOPTION OF FEASIBLE SOLUTIONS OF A NONLINEAR PROGRAMMING MODEL

ALVES, Luiz Claudio Lopes * *IBGE, Brazil*

The present work presents a multicriteria confiability methodology whith the adoption of feasible solutions of the original objective function (minimum total cost of production), of a nonlinear programming model for equipment selection in a Just in Time environment, when we make its optimization considering one more criteria together (minimum total time of production).

SPORTS SCHEDULING USING MODERN MANAGEMENT TECHNIQUES

DAZA-ESCORCIA, Julio Mario* *Corporación Politécnico de la Costa Atlántica, Colombia*
ÁLVAREZ-MENDOZA, Anny Sofía *Universidad Autónoma del Caribe, Colombia*
FERRER-VÁSQUEZ, Mario *Alfaisal University, Saudi Arabia*

This article presents the way how to deal with the confession of the first division fixture of Colombian professional football through modern management techniques, such as operations research. This fixture must meet certain conditions requested by the association of Colombian Professional Football (FPC), which organizes the tournament. This research takes into account criteria such as geographic is particularly important because the provision of some equipment in extreme parts of the country involves long journeys, often conducted by land travel, among other variables to be discussed in detail and contribute to the proper administration of the sport more attractive in the world. This work is framed in a very studied operations management, known as the sports scheduling. This article presents the criteria used to define the efficiency of a fixture in terms of sporting equity, how operational and economic considerations were introduced into the manufacturing process and how the proposed model, with its implementation, provide flexibility to the process without unprecedented. In addition to increasing the attractiveness of the tournament, these factors together, streamline the manufacturing process of the fixture, making it more transparent and attractive to both the leaders of the football teams as the followers of each of the participants in the tournament.

ANALYSIS OF DIVERSE OPTIMIZATION ALGORITHMS FOR PUMP SCHEDULING IN WATER SUPPLY SYSTEMS

COELHO, Bernardete* *University of Aveiro, Portugal*
TAVARES, Amilcar *University of Aveiro, Portugal*
ANDRADE-CAMPOS, António *University of Aveiro, Portugal*

Nowadays, the major expenses with water supply systems (WSS) correspond to energy consumption. The number of scientific works dealing with operational optimization in WSS has been increasing over the past years, demonstrating significant reductions on energy costs and consumption. Pump stations usually represent the major portion of total energy costs in WSS. Consequently, in this work, it is pretended to give a contribution for energy efficiency improvement in pump stations. Generally, in WSS, the pumps are switched on when the reservoirs, responsible for supplying certain populations, reach their minimum levels. These pumps are only switched off when the reservoirs reach their maximum levels. The introduction of an operational pump pattern adapted to the energy tariff variation and the consumption patterns of the populations can optimize pump stations operations, minimizing energy costs significantly. However, the process of finding the best pattern can present difficulties due to the complexity of some WSS (multiple pumps, multiple reservoirs, nonlinear behavior of the systems, etc). In this work, an interface was developed with the aim of applying different optimization algorithms for pump scheduling in WSS. The interface makes an automatic connection between a hydraulic simulator (EPANET 2.0) and the different optimization algorithms selected, providing, after multiple iterations and evaluations, an optimal pump pattern for a certain water supply network represented. Two different examples of water supply networks are introduced in this study in order to validate the developed methodology. For both WSS, classic and meta-heuristic optimization algorithms are tested and analyzed.

TOWARDS AUTOMATIC OPTIMIZATION OF FLOW CHANNEL GEOMETRIES IN COMPLEX MULTI-LEVEL DIES FOR FILM EXTRUSION

HOPMANN, Christian *Institute of Plastics Processing, Germany*
EILBRACHT, Stephan* *Institute of Plastics Processing, Germany*

Packaging, automotive and medical industries are major sectors with high demands and specifications for polymer products, e.g. polymer films. Due to the complexity of the material and the high specifications regarding the film quality and homogeneity a key position is the rheological design of the die used for the primary forming of the polymer melt. However, current rheological die design is mostly based on experience and some basic analytical equations. The use of die design software e.g. computational fluid dynamics (CFD) is rare. Regardless whether the chosen die design approach is based on experience or CFD, the entire process is time consuming, costly, ties down manpower and highly depends on the experience, knowledge and training of the responsible engineers. In many cases, there is a serious effort for trial-and-error-testing. In order to optimize the rheological die design approach in polymer extrusion, a new die design software for fluid flows in complex multi-level dies is developed at the Institute of Plastics Processing, RWTH Aachen University. In this paper, a flow simulation model will be presented that is able to calculate the melt velocity distribution in the extrusion die. The model is based on the control volume approach, also referred to as "network theory", that consistently employs an analogy of electrical engineering (voltage, current, resistance) and hydrodynamics (pressure drop, volume flow, flow resistance). Kirchhoff's laws are being used and a resistance network is automatically generated that substitutes the multi-level extrusion die geometry. A system of equations describing the flow process is derived that is characterized by a sparse matrix. Calculation times are less than a minute. Hence, the analysis and comparison of a large number of different flow channel geometries can be done within reasonable time. The computational results are analyzed employing a fitness function approach. Applying optimization techniques the best solutions are identified automatically. In order to further improve automation in rheological die design, self-optimization algorithms such as evolutionary algorithms, particle swarm optimization or simplex strategies are implemented and tested with regard to their suitability of finding good flow channel geometries within reasonable time. Thus, an overall improvement of the die quality, the quality of the produced polymer products and the costs for man-hours and trial-and-error-testing is expected.

A MILP MODEL FOR SIMULTANEOUS SUPPLY CHAIN AND FACILITY DESIGN CONSIDERING PRODUCTION SCHEDULING

FUMERO, Yanina *INGAR (CONICET-UTN), Argentina*
MONTAGNA, Jorge M. *INGAR (CONICET-UTN), Argentina*
CORSANO, Gabriela* *INGAR (CONICET-UTN), Argentina*

Several authors have addressed to the integration of supply chain (SC) decisions as an important and still open issue. The importance of interactions among decision levels is that significant benefits can be obtained by approaching the network as a whole and considering its various components simultaneously. Despite the growing body of literature about SC and related decisions (design, planning, scheduling, etc.), to the best of our knowledge, an integrated SC and plant design considering production scheduling remains to be addressed. In this work, a new formulation for the simultaneous design of SC and involved plants is presented, where the scheduling is specially considered through the use of mixed product campaigns (MPC). Besides providing a more steady supply of products from the commercial point of view, the sequencing of batches of different products in a MPC can reduce idle times and improve the utilization of the equipment. This approach is specially valid for stable contexts. In particular, this formulation is focused on the case of multiproduct batch plants. The SC considered in this work comprises three echelons: suppliers, multiproduct batch plants, and customers. Decisions regarding SC network such as nodes selection, supplier selection, material flows among nodes, and products distribution are jointly considered with multiproduct plant design (out of phase unit duplication and unit sizes), mixed product campaigns composition (number of batches of each product), and their sequencing in order to meet a specified economic criterion fulfilling demand requirements. With the aim of avoiding non linear formulations, some model assumptions are posed: discrete sizes for process units, maximum number of product batches in the campaign, and a set of discrete values for the number of campaign repetitions for each installed plant. The proposed model is applied to several examples where the different tradeoffs between plants design and scheduling and network design are assessed.

OPTIMAL DESIGN OF TRANSPORTATION NETWORKS BY MEANS OF A CONTINUUM MODEL

CORTINEZ, Victor Hugo* *Centro de Investigaciones en Mecánica Teórica y Aplicada, Universidad Tecnológica Nacional, Argentina*
DOMINGUEZ, Patricia Neri *Dto. de ingeniería, Universidad Nacional del Sur, Argentina*

Congestion of urban traffic is one of the most important problems in modern cities. In order to alleviate this phenomenon it is possible to make different modifications in the traffic network such as construction of new arteries or freeways, increase of the number of lanes in certain avenues, traffic lights implementation, etc. The objective is to decrease the total travel time. In order to analyze appropriately the effects of different network, changes on the traffic conditions, it is necessary to use mathematical modelling. One of the best well known models for urban traffic is based on the Wardrop principle. This last one establishes that in equilibrium conditions, users will choice those routes that imply minimizing their travel times. This model leads to an optimization problem having as unknowns the vehicular flows at each link (street, avenue, or freeway) of the transportation network. By means of traffic models, it is possible to compare different design alternatives in order to select that one fulfilling the desired objective. Accordingly, the transportation network design is mathematically formulated as one of optimization in two levels. In this work an alternative approach is proposed. This is based on the use of a continuum model for predicting the traffic flows in every link of the network. This model is expressed by means of a non-linear system of differential equations, of the diffusion type, that is appropriately solved by means of the finite element method. The computational times are generally much lower than those of the classical discrete approach. It is shown that this methodology yields very accurate results with relatively low computational times.

LAYOUT OPTIMIZATION OF A WIND FARM USING GENETIC ALGORITHM

GASPERIN JR, Roberto* *Universidade do Vale do Rio dos Sinos -UNISINOS, Brazil*
INDRUSIAK, Maria Luiza Sperb *Universidade do Vale do Rio dos Sinos - UNISINOS, Brazil*

The performance of a wind farm is related to several factors, both physical and economic. They can be separated into three groups: wind turbines, which represent three quarters of total investment, civil and electrical infrastructure that divide equally one quarter of total investment The need to optimize the generation of wind farms therefore becomes essential to increase the production of electricity using smaller areas and seeking the best use of generators, reducing installation costs for the same power. The main concern of this paper is to model the parameters of the objective function in a simplified way, but closer to the real. The parameters addressed, such as the wake phenomenon, power curve, Weibull function, modeling the allowable surface etc. exhibit non-linear characteristics, which makes the problem ideal for applying a genetic algorithm. Therefore in this work is applied a simple genetic algorithm that has as main objective the maximization of generation by optimizing the layout of a wind farm. With these results we evaluate the efficiency of genetic algorithm in the implementation in layout designs of wind farms.

PREDICTOR-CORRECTOR PRIMAL-DUAL INTERIOR POINT METHOD IN ECONOMIC DISPATCH PROBLEM WITH ENVIRONMENTAL CONSTRAINT

STANZANI, Amélia de Lorena* *FEB/UNESP, Bauru-SP, Brazil*
BALBO, Antonio Roberto *FC/UNESP, Bauru-SP, Brazil*
OLIVEIRA, Larissa Tebaldi *ICMC/USP, São Carlos - SP, Brazil*

This work proposes the implementation of primal-dual interior point method (PDIPM), with predictor-corrector procedure, for quadratic programming with linear and quadratic constraints and bounded variables, and its application in multiobjective problems of economic and environmental dispatch (EED), found in electrical engineering. It considers the environmental function as an additional constraint to the classical economic dispatch problem, bounded by a constant representing the allowable maximum emission. This strategy, used to solve multiobjective problem, is called e-restricted method and can be found in Miettinen (1999). In this approach we consider two different modeling. The first model uses an unique bound of allowable maximum emission for all generation system. The second model uses an allowable maximum emission bound for each system generator, such that, this formulation highlights the individual characteristics of each generator, not only using operating bounds as emission limits. The PDIPM has showed its efficiency for solving EED problems. This method is a variant of Karmarkar's projective transformation algorithm (1984) and was initially analyzed and presented in Monteiro et al. (1990) and Kojima (1989). The theoretical demonstration of the polynomial time complexity was realised by these authors. The PDIPM

algorithm proposed in this work is defined using the logarithmic barrier function, defined in Frisch (1995) and Fiacco (1968), and the predictor-corrector procedure, defined in Mehrotra (1992) and Wu and Debs (1994), that seeking to attenuate the required computational effort, by the primal-dual interior point method, in the search directions determination. An extension to modified logarithmic barrier case is done based on Polyak (1992) and it helps to resolve the second model. Computational tests carried out in C++, for determining approximate solutions of the problems, were realized using the e-restricted strategy for resolution of the multiobjective problems. This research demonstrates the efficiency of PDIPM when compared to the co-evolutive, hybrid and cultural genetic algorithms, published respectively in Samed (2004) and Rodrigues (2007), as well to the primal-dual interior point method with line search procedure founded in Souza (2010).

SYNCHRONISATION AND CONTROL OF PROLIFERATION IN CYCLING CELL POPULATION MODELS WITH AGE STRUCTURE

FERCOQ, Olivier* *INRIA Saclay and CMAP Ecole Polytechnique*, *France*

We present and analyse a mathematical model for the optimization of cancer drug treatments in cycling cell population models with age structure. We consider a drug, 5-FluoroUracil (5-FU), that prevents cells from starting mitosis. The proliferating healthy and cancer cell populations are represented by the same age-structured model of the McKendrick type, with different physiological controls for the two cases. Each dynamics is given by physiologically structured PDEs where the dynamic variables are the number of cells of each age in each phase of the proliferation cycle: first growth phase (G1), DNA synthesis followed by second growth phase (S-G2) and mitosis (M), and the only structure variable is age in the phase. The parameters of the model are the death rates and transitions from a phase to the next in the cell cycle. In this work, we assume that proliferation is physiologically controlled by a circadian clock, which implies that the coefficients of the model are not only age and phase-dependent but also 24-h periodic functions. Our fundamental hypothesis is that healthy and cancer cells proliferate following the same model, but that cancer cells are characterized by a looser response to the circadian control, which gives them a proliferation advantage. We show how recent fluorescence-based image modelling techniques performed at the single cell level in proliferating cell populations allow one to identify some key parameters of the population dynamics. Then, we consider time-dependent 5-FU infusions that disrupt the transition from phase G2 to M. We study the problem of minimizing the growth rate of the cancer cell population, modeled by the Floquet eigenvalue of the population dynamics, with the constraint that the growth rate of the healthy cell population remains over a given toxicity threshold. The goal is to find (periodic) chemotherapy schedules that are viable in the long term and effective in the fight against cancer. When we discretize the problem, the Floquet eigenvalues are approached by the Perron eigenvalues of sparse nonnegative matrices. We developed a multiplier method for the local optimization of the growth rates, that takes advantage of a low rank property of the gradient of the Perron eigenvalue. This talk relies on Billy, Clairambault, Fercoq, Gaubert, Lepoutre, Ouillon, Saito, Synchronisation and control of proliferation in cycling cell population models with age structure, to appear in Mathematics and Computers in Simulation.

Inverse Problems and Parameters Estimation

PARALLELIZED THE FELDKAMP ALGORITHM FOR 3D RECONSTRUCTION OF TOMOGRAPHIC IMAGES USING GPUS AND CUDA C

DOMINGUEZ, Joel Sánchez* *UERJ, Brazil*
OLIVEIRA, Luis Fernando de *UERJ, Brazil*
JUNIOR, Nilton Alves *CBPF, Brazil*
DE ASSIS, Joaquim Teixeira *UERJ, Brazil*

This paper presents the study and proposes the implementation of a software for tridimensional reconstruction of images obtained with a tomography system using the capabilities of graphics processing units (GPU). The reconstruction using the Feldkamp, David e Kress (FDK) algorithm is shown and is also analyzed the use of GPUs and CUDA C language for parallel implementation of the method, aiming to leverage the processing power of GPUs to solve computational problems with large computational cost, highly parallelizable. Discussed the potential of GPUs and explained its advantages to solve such problems. The results in terms of execution time will be compared with non-parallel implementations of the algorithm and analyzed the differences.

IDENTIFICATION AND RECONSTRUCTION OF ELASTIC BODY FORCES FROM BOUNDARY MEASUREMENTS

ALVES, Carlos J.S. *CEMAT/IST and Department of mathematics, IST TULisbon, Portugal*
MARTINS, Nuno F. M.* *CEMAT/IST and Department of mathematics, FCT/UNL, Portugal*

Consider an elastic isotropic and homogeneous two dimensional medium. Suppose that the displacement field satisfies the elastodynamic system of equations in harmonic time (Navier system of equations), with some body force, f. On the boundary of the medium, we prescribe the displacement vector and measure the generated traction force, for a range of frequencies. In this talk, we address the identification and reconstruction of the source function f from the knowledge of the above pair of boundary Cauchy data (displacement and traction). This model arises in several non-destructive evaluation problems in engineering. It is well known that, under some restrictions on the class of elastic sources, a single pair of Cauchy data is sufficient to fully identify f. However, in a more general framework, no such identification is possible. We discuss this identification problem considering an extended range of Cauchy data: First, by assuming the full knowledge of the displacement to traction map (the so called DtN map); Second, by considering, for fixed displacement, the frequency to traction map. We propose a reconstruction method based on Betti's formula and present several numerical simulations in order to illustrate the feasibility of the reconstruction method.

INVERSE DETERMINATION OF SOIL CHARACTERISTICS WITH A BENCH-SCALE CENTRIFUGE

MALENGIER, Benny* *Ghent University, Belgium*
KISON, Pavol *Comenius University Bratislava, SLOVAK REPUBLIC*
DI EMIDIO, Gemmina *Ghent University, Belgium*
PEIFFER, Herman *Ghent University, Belgium*

We utilize a bench-scale centrifuge to speed up the process of porous media infiltration. This allows to obtain measurements in a fraction of the time needed by standard infiltration methods, escpecially for clayey soils. By measuring only transient data like water level in an inflow or outflow chamber, gravitational center of the sample, or the rotational momentum of the sample, it is possible to determine the soil characteristics. This is done by solving the inverse problem based on the mathematical model for saturated and unsaturated water infiltration in soil. The model for the unsaturated flow is based on Richards' equation and the Van Genuchten-Mualem formula. We present the experimental set-up, accuracy of the measurements, and the numerical solution method. Results are compared with results from standard tests. For saturated flow we compare with standard tests and the classical formula for hydraulic conductivity in a centrifuge from two discrete measurements.

INVERSE PARAMETER IDENTIFICATION FOR A BRANCHING 1D ARTERIAL BLOOD FLOW NETWORK

BOGAERS, Alfred Edward Jules* *CSIR, South Africa*
KOK, Schalk *CSIR, South Africa*
FRANZ, Thomas *University of Cape Town, South Africa*
REDDY, BD (Daya) *University of Cape Town, South Africa*

Haemodialyses is a medical treatment whereby excess water and waste substances are removed from the blood using an external filter device. It is not uncommon for haemodialysis patients to suffer from congestive heart failure due to the treatment. One of the current hypotheses is that improperly sized shunts inserted for purposes of the dialysis treatment (allowing for an abnormally high amount of blood to be drained from the arterial to venous network) is at least partially responsible for the heart failure. A one dimensional blood flow model could therefore be a useful tool to provide medical practitioners with a guide to choosing appropriately sized shunts. However, due to the physiological uniqueness of each patient, it would be necessary for this 1D arterial-venous model to be representative of a given patient. In this paper we aim to investigate the invertability of a branching 1D arterial network. The analysis is performed using a 1D finite volume code implemented on a staggered grid to solve the one dimensional area-velocity continuity equations. The model has been demonstrated to accurately capture the various reflecting pressure waves for a network with arbitrary discontinuities in compliance as well as the discontinuities present due to branching. For this proof of concept it is assumed that the topology of the major arteries within the network will remain consistent from patient to patient. The material properties for each segment of the arterial network are set as free parameters, where the lengths of each artery and unstressed area are assumed to be known. The heart input pulse is modelled as a half sinusoidal pressure pulse, where the amplitude and period of the pulse are also included as design variables along with terminal artery resistances. The synthetic data is obtained by running a numerical analysis of the 1D network for a given set of parameters. The cost function for the inverse optimisation problem is based on the difference in pressure and mass flow rate data in time. We will demonstrate the invertibality of the problem as a function of the number of measurement points within the network as well as the number of data points within each time signal. Lastly, we will show how the addition of increasing levels of noise to the synthetic data influences the ability of obtaining the correct system parameters.

SIMULTANEOUS ESTIMATION OF EXPERIMENTAL AND MATERIAL PARAMETERS.

JANSEN VAN RENSBURG, Gerhardus J.* *Council for Scientific and Industrial Research, South Africa*
KOK, Schalk *Council for Scientific and Industrial Research, South Africa*
WILKE, Daniel N. *The University of Pretoria, South Africa*

Material testing usually makes use of a simple geometry subjected to a simple load case. The goal is to obtain uniform stress states so that simple analytical post processing would produce stress-strain curves. Specific standards and procedures are in place for these tests. If a compression test is performed under ideal

conditions, experimental data can be used to calibrate a material model with little effort. However, in the case of hardmetal compression testing, the high stiffness of the specimen compared to the effective stiffness of the test machine can result in a non-ideal material test. For this work, experimental data (hydraulic cylinder displacement, load cell and strain guages) for a number of compression tests are available at different temperatures during loading and unloading. This data clearly demonstrates that a non-uniform stress state develops during the compression test, primarily due to insufficient testing frame stiffness. The data also indicates that the specimen strain rate is not constant, although the hydraulic cylinder crosshead speed remains constant. The finite element method is used to simulate the imperfect compression tests. The effective stiffness of the testing frame is included in the model, and a bending moment is applied gradually to the specimen as the test proceeds. Using the available experimental data, the current work aims to find the material model parameters (for a state variable based work hardening law that is strain rate and temperature dependent), testing machine stiffness and boundary conditions (bending moment) that best reproduce the experimental data by solving an inverse problem. The main focus of this conference contribution is the problem setup and formulation of the objective function. The invertibility of this type of problem is inspected using virtual experiments, where representative experimental data is generated using a chosen set of material parameters, machine stiffness and bending moment. It is then required to obtain the correct transient response by solving the inverse problem as if the material parameters and effective boundary conditions were unknown. The objective function formulation that best returns the known model parameter values is sought for use in the actual problem.

HEAT TRANSFER COEFFICIENT ESTIMATION OF AN INTERNAL COMBUSTION ENGINE USING PARTICLE FILTERS

HAMILTON, Fabiana Cheade *COPPE/UFRJ, Brazil*
CARVALHO, Rogério Nascimento de* *COPPE/UFRJ, Brazil*
COLACO, Marcelo *COPPE/UFRJ, Brazil*
LEIROZ, Albino J. K. *COPPE/UFRJ, Brazil*

The continuous growing of the worldwide vehicle's fleet is leading to many initiatives and government policies for the achievement of lower pollutant and GHG emissions together with an energetic efficiency improvement. New technologies are being developed around the world in order to accomplish with very restricted regulated targets for the next years in many countries. Downsizing, electronic controls, after treatments, gasoline direct injection, hybridization and electric propulsion are some of these new developments. Besides that, many researches in fuels and lubricants are taking place. New gasoline and diesel quality requirements include low-sulphur content, better anti-knocking and cetane indexes and low friction additives, for instance. Alternative fuels are also under continuous development and improvement, such as biofuels and natural gas. Nevertheless, almost all of these technologies are still based on internal combustion engines and the correct understanding of phenomena inside these machines is fundamental. These processes are very complex and the combustion study involves the knowledge of chemical reaction kinetics of distinct organic components, turbulent and multiphase flows, flame speed, heat transfer characteristics and engine geometry. Numerical simulation is an important tool to support these developments and some commercial packages are already available focused on engine design. However, in general these softwares are not able to deal with different specific fuel formulations, exactly due to the high level complexity of the combustion phenomena mathematical modeling. Stochastic methods appear as a very useful alternative to deterministic ones, since they are able to predict state unknowns based on available measured data and the prior understanding of the physical phenomena and measuring devices. In this paper is presented the use of Particle filters applied on the heat transfer coefficient estimation of a combustion process in an Otto's ICE.

ESTIMATION OF PARAMETERS IN AN INVERSE HEAT CONDUCTION PROBLEM BY USING A MARKOV CHAIN MONTE CARLO (MCMC) METHOD

PADILHA, Ricardo de Sá* *UFRJ, Brazil*
ORLANDE, Hélcio Rangel Barreto *UFRJ, Brazil*
PAEZ, Marina Silva *UFRJ, Brazil*

This paper presents an application of the Markov Chain Monte Carlo (MCMC) method for the estimation of parameters in an inverse heat conduction problem under the Bayesian point of view. The physical problem considered here involves the heating of a solid cylinder made of polytetrafluoroethylene (PTFE) imersed

in a temperature-controlled hot water bath. The main aim is the identification of the following unknown parameters appearing in the mathematical formulation of the transient physical problem: cylinder thermal conductivity, its volumetric heat capacity and the heat transfer coefficient between the cylinder and water. Temperature measurements taken at selected positions within the cylinder are used for the inverse analysis. Analyses of the sensitivity coefficients with respect to each of the unknown parameters and of some statistics are presented and discussed. We present results obtained with simulated and actual experimental measurements.

BAYESIAN INFERENCE APPROACH TO IDENTIFY CONSTITUTIVE PARAMETERS OF VISCOELASTIC MATERIALS

DE SOUZA, Hudson Viegas Alves Fernandes* *PETROBRAS Company, Brazil*
CASTELLO, Daniel Alves *COPPE/UFRJ, Brazil*
MATT, Carlos Frederico Trotta *CEPEL, Brazil*

This work is aimed at estimating constitutive parameters of a model for viscoelastic materials. The constitutive model that was chosen to represent the dynamics of these materials is based on the concept of internal variables and the associated inverse problem is built on data from either time or frequency domain. A statistical inversion procedure, based on bayesian inference technique, is used to estimate the parameters as marginal posterior probability distributions. Markov chain Monte Carlo sampling methods (MCMC), with the Metropolis-Hastings algorithm, are employed in order to draw samples from the posterior distributions. A mass-spring-damper system with one degree of freedom, attached to a viscoelastic core, is studied, and problems related to the parameter estimation process as well as the computation of posterior quantities are investigated. A sandwich structure is also used for the analyses, whose model equations are solved by the finite element method. Finally, optimum experiment design procedures are applied to this system in order to maximize the information level about the estimated parameters.

OPTIMIZING SENSOR ALLOCATION USING RECONCILED DATA IN SYSTEMS WITH SCARCE MEASUREMENTS: MINLP AND MILP APPROACHES

NARCISO, Marcos Vinícius Almeida* *UFBA, Brazil*
DO VALLE, Edson Cordeiro *UFBA, Brazil*
KIPERSTOK, Asher *UFBA, Brazil*
KALID, Ricardo de Araújo *UFBA, Brazil*

The positioning of new flow rates sensors in an industrial plant is a challenge problem, especially in water networks where they are rarely found. The purpose of this paper is to present new approaches to obtain the optimal position of a new flow rates sensor set in networks with scarce, or none, sensors. To perform such task, we use the results of a data reconciliation using the concepts of estimation of non-measured process stream flow rates and its confidence information, named, Quality of Information (QI). First, the mapping of the network topology and flow rates was performed to feed a data reconciliation with QI. Second, with the reconciled data, some runs in objective function, with some variation in optimization parameters, were carried out to obtain the optimal positioning of the new sensor set. The optimization was carried out respecting mass and economic constraints of the measurement system, minimizing the objective function proposed. MINLP and MILP approaches were applied to some academic examples. The results of the methodology show that it is appropriated for industrial plants with scarce, or none, measurements.

A COMPARISON OF THE ITERATIVE REGULARIZATION TECHNIQUE AND THE KALMAN FILTER FOR THE ESTIMATION OF BOUNDARY HEAT FLUX IN GRINDING

CARVALHO, Rogério Nascimento de* *COPPE/UFRJ, Brazil*
ORLANDE, Hélcio Rangel Barreto *COPPE/UFRJ, Brazil*
COLACO, Marcelo *COPPE/UFRJ, Brazil*

Material removal by grinding process requires high energy input levels that are generally converted into heat in the workpiece surface, mainly in the grinding zone. Accurate analysis of heat transfer in this kind of process is important to reduce damages caused by thermal stresses originated from nonuniform cooling or very concentrated energy input. By using temperature measurements taken inside the workpiece, estimations of heat flux magnitudes can be obtained with the application of inverse heat transfer techniques.

Inverse analyses are nowadays becoming popular, not only as a matter of research works, but as practical engineering tools as well. This paper presents the estimation of surface heat flux in grinding. Both Alifanov's iterative iterative regularization approach, in the form of the conjugate gradient method with adjoint problem formulation, and the Kalman filter for the solution of state estimation problem, are applied to the solution of the inverse problem of interest in this work. The inverse problem is solved based on temperature measurements of sensors installed inside the workpiece. A comparison of these techniques is made in order to verify their strengths and weaknesses, mainly in terms of accuracy and computational efforts.

THERMOCHEMICAL PROPERTIES ESTIMATION FOR BIODIESEL RELATED MIXTURES

BORGHI, Daniela de Freitas* *State University of Campinas, Brazil*
ABREU, Charlles Rubber de Almeida *Federal University of Rio de Janeiro, Brazil*
GUIRARDELLO, Reginaldo *State University of Campinas, Brazil*

Currently, biodiesel production has been studied in several countries due to exhaust preview of oil resources and because of the characteristics of biodiesel, which is a fuel with environmental advantages over the emission of pollutants gases. Brazil is a large producer of soybeans and ethanol, thus the country has great potential to become reference as a producer of ethylic soybean biodiesel. However, data on the thermochemical properties of compounds in the process of producing biodiesel are rarely available. Within this context, the present work aimed to obtain the thermochemical properties - standard enthalpies of formation at 298.15 K, heat capacity (Cp), entropy (S) and sigma profile - of compounds in the biodiesel production process from using a methodologies described in the literature (Osmont et al., 2007) which uses the method Ab initio B3LYP/6-31G (d, p) and the Gaussian 03 software to obtain the gas phase properties and the software MOPAC to generate the sigma profiles for these molecules to be used directly in the COSMO-SAC model. In the method used, the correlation between the data of the experimental standard enthalpy of formation at 298.15 K and the calculated by them using the methodology developed has been very good. Therefore, the data of thermochemical properties obtained in this study may be useful for carrying out the calculation of phase equilibrium of the biodiesel production process. The methodology was used in the present work to obtain the properties of glycerol, dodecanoic acid, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, oleic acid monoester, oleic acid diester and oleic acid triester and methyl oleate.

PARAMETERS RECONSTRUCTION IN SECOND ORDER ELLIPTIC EQUATIONS

ROBERTY, Nilson Costa* *COPPE/Federal University of Rio de Janeiro, Brazil*

The determination of unknown parameters related with both intensities and support of sources and materials coefficients in second order elliptic equations models are investigated in systems with over determination of boundary conditions. Specifically in the case of sources, it can be shown that a complete reconstruction is not possible even on models with many boundary values measurements. Two methodologies are presented. One based on the Lagrange-Green formula and named Reciprocity gap functional. In source problems, it formulates a system of Fredholm integral equations that can be solved independently of the solution of the direct problem. In the case of parameters related with conductivity or potential, this system can be coupled with the direct problem and gives additional equations necessary for the parameters determination. The second methodology is based on splinting the over determinate data on the boundary to formulates two well posed direct initial mixed boundary values problems for each Cauchy data on the boundary. Parameters are determined by non differentiable minimization of the discrepancy functionals defined with solutions obtained with guess parameters values. Numerical implementations based on finite elements numerical solutions are presented in the two dimensional square $(-1,+1)*(-1,+1)$ with sources, conductivity and potential supported by an unknown characteristic square shape interior domain. The Nelder-Mead Simplex method [LagariasEtall1998] is used to search for parameters that minimizes the defined discrepancy functional.

Mathematical Optimization Techniques

INTERIOR EPIGRAPH METHOD FOR NONSMOOTH AND NONCONVEX OPTIMIZATION VIA GENERALIZED AUGMENTED LAGRANGIAN DUALITY

FREIRE, Wilhelm* *UFJF, Brazil*
BURACHIK, Regina *UniSA, Australia*
KAYA, Yalcin *UniSA, Australia*

We propose a new method, called Interior Epigraph Method (IEM), for con- strained nonsmooth and nonconvex optimization. The method uses a gener- alized augmented lagrangian duality scheme, which was previously employed in a De°ected Subgradient (DSG) method. IEM replaces the updates used by the DSG by a tailored version of the Nonsmooth Feasible Directions Al- gorithm (NFDA). NFDA was proposed by Freire and co-workers for solving unconstrained, nonsmooth and convex problems. We use a modi¯ed version of NFDA for solving the (unconstrained) dual problem which takes advantage of the special structure of the epigraph of the dual function. We prove that all the accumulations points of the primal sequence generated by IEM are so- lutions of the original problem. We carry out numerical experiments by using test problems from the literature. In particular, we study several instances of the kissing number problem, previously solved by using an augmented penalty method, the DSG method, as well as the popular di®erentiable solvers AL- BOX, Ipopt and LANCELOT. Our experiments show that the quality of the solutions obtained by IEM is comparable with (and sometimes favorable over) those obtained by all other solvers mentioned above.

THE ADJOINT METHOD IN OPTIMIZATION

TOADER, Anca-Maria* *CMAF, Portugal*

The Adjoint Method goes back to the works of Pontryagin in the framework of Odinary Differential Equations. In the eighties, J. Cea employed the Adjoint Method in a practical way, from the perspective of Lagrange multipliers. Since then, applications of the Adjoint Method were successfully used in Shape Optimization, Topology Optimization and very recently and to optimize eigenvalues and eigenmodes. Several examples will be discussed in each case and a special emphasis will be given to the Adjoint Method applyed to the optimization of eigenvalues and eigenmodes. In this framework the direct problem does not involve a bilinear form and a linear form as usual in other applications. However it is possible to follow the spirit of the method and deduce N adjoint problems and to obtain N adjoint states, where N is the number of eigenvalues to be optimized. This study was motivated by a real optimization problem coming from the necessity of non-destructive damage detection in concrete dams.

USING FAIPA FOR SOLVING NONLINEAR COMPLEMENTARITY PROBLEM

MAZORCHE, Sandro Rodrigues* *UFJF, Brazil*
HERSKOVITS, José *UFRJ, Brazil*

We discuss the computational implementation of the FAIPA complementarity problem to solve non-linear. The FAIPA is an interior point algorithm for minimizing a nonlinear function with equality and inequality constraints. The algorithm requires a starting point x_0 within the region defined by the restrictions inequalities, generating a sequence of points also within this region. Through a new update rule for lambda

and the matrix B in algorithm FAIPA the search direction obtained by FAIPA system will generate a sequence of points inside the feasible region converging the solution of the Nonlinear Complementarity. We will see the advantages that provides FAIPA when using this new update and a set of test problems verify the efficiency of this method over other types of algorithms that are used to solve problems of non-linear complementarity.

A GENERAL TECHNIQUE FOR INTERIOR POINT METHODS FOR NONSMOOTH OPTIMIZATION

TANAKA FILHO, Mario * *Universidade Federal do Oeste do Pará, Brazil*
HERSKOVITS, José *Federal University of Rio de Janeiro, Brazil*

We present a general view on a new family of algorithms for nonsmooth optimization that includes convex and nonconvex problems as well as the unconstrained or the inequality constrained cases, [1,2] Our approach combines some basic ideas of cutting planes and bundle methods with a feasible descent search direction employed in FAIPA, the Feasible Direction Interior Point Algorithm [3], for constrained smooth optimization. A sequence of auxiliary problems is built, were the constraints of the problem are approximated by planes, as well as the epigraph of objective function. At each iteration a search direction for the auxiliary problem is computed solving two systems of linear equations, as in FAIPA. The algorithm generates a sequence of interior points whose accumulation points are solutions of the original problem. We discuss about the computer implementation of the method, in particular the conditioning and the numerical solution of the internal linear systems. Numerical results obtained using the proposed algorithms for a set of test problems are presented. This results show that the present technique is strong and efficient, when compared with others methods.[1] Herskovits, J., Freire, W., Tanaka Filho, M. Canelas, A. A feasible directions method for nonsmooth convex optimization. Struct. Multidisc. Optim. v. 44:363–377, 2011.[2] Karmitsa, N., Tanaka Filho, M. Herskovits, J. Globally Convergent Cutting Plane Method for Nonconvex Nonsmooth Minimization. Journal of. Optim. Theory Appl. , v. 148, n 3, 528-549, 2010.[3] Herskovits, J. Feasible direction interior-point technique for nonlinear optimization, Journal of Optimization Theory and Applications, v. 99, pp. 121–146, 1998.

ON THE STUDY OF A MEHROTRA-TYPE PREDICTOR-CORRECTOR ALGORITHM

TEIXEIRA, A.* *UTAD / CIO, Portugal*
ALMEIDA, R. *UTAD / CIDMA, Portugal*

Bastos and Paixão presented a new feasible predictor-corrector Linear Programming variant of Mehrotra's algorithm, that just makes two line searches per iteration and so it has the advantage of decreasing the running time of each iteration. The major differences between this new variant and the classical predictor-corrector for Linear Programming are: the predictor direction is computed as in the primal-dual methods, it uses the same duality measure both for the predictor and the corrector directions and no line search is needed to obtain the duality measure. Bastos and Paixão also showed that this new version was computationally more efficient than the original one for the class of problems studied in that work. Based on these good computational results, Teixeira and Almeida recently proved that this algorithm has polynomial complexity. Motivated by these complexity results, in the present work we continue to study the theoretical efficiency of this algorithm. Using the negative infinity norm neighborhood with parameter 0.5, some technical results necessary to analyze the convergence are proven; furthermore, the type of convergence of the algorithm is thoroughly discussed.

OPTIMIZATION OF STRUCTURAL SYSTEMS WITH AN INTERIOR POINT ALGORITHM FOR SEMIDEFINITE PROGRAMMING.

AROZTEGUI, Miguel* *UFRN, Brazil*
ROCHE, Jean *Institut Élie Cartan, France*
HERSKOVITS, José *COPPE/UFRJ, Brazil*

In this contribution a new algorithm for nonlinear convex semidefinite programming is presented. We apply our method to semidefinite models for the minimum weight problem subject to a natural frequency constraint and the problem of maximization of the natural frequency subject to a volume constraint. The numerical technique is based in the solution of Karush-Kuhn-Tucker first order optimality conditions. The method obtains a decreasing feasible solution. Two linear systems with the same coefficient matrix are solved and an inexact line search is then performed. The numerical results show high robustness of the proposed method.

COMBINING LEVEL AND PROXIMAL BUNDLE METHODS FOR CONVEX OPTIMIZATION

OLIVEIRA, Welington* *IMPA, Brazil*

We give a bundle method for minimizing a possibly nonsmooth convex function that combines both level and proximal bundle methods. Most bundle algorithms use information to build linearizations for the objective function. The piecewise maximum of linearizations defines a cutting-plane model that enters the quadratic program (QP) whose solution gives the next iterate. Proximal bundle methods use the model in the QP objective function, while level methods use the model in the QP constraints. We consider the proximal form of a bundle algorithm that defines new iterates by alternating the solution of the two different quadratic programs. In contrast to the classical proximal bundle method, our new variant is able to update lower bounds for the objective function allowing an additional stopping test based on the optimality gap. Furthermore, the projections onto successive approximations of level sets provide Lagrange multipliers that are used to update the proximal parameter, thus accelerating the optimization process. Some numerical experiments comparing our variant with level and proximal bundle methods are given.

NUMERICAL SOLUTION OF MOVING BOUNDARY PROBLEM INVOLVING PARABOLIC EQUATIONS USING NONLINEAR COMPLEMENTARITY ALGORITHM

CHAPIRO, Grigori* *UFJF, Brazil*
MAZORCHE, Sandro Rodrigues *UFJF, Brazil*
HERSKOVITS, José *COPPE/UFRJ, Brazil*

Parabolic type problems involving a variational and complementarity formulation arise in mathematical models of several applications in Engineering, Economy, Biology and different branches of Physics. These kinds of problems present several analytical and numerical difficulties related, for example, to time evolution and moving boundary. We implemented a numerical method based on the finite difference scheme for time evolution and nonlinear complementarity algorithm for solving the problem at each time step. We used the implicit finite difference scheme with adaptative time step implementation which allows us to use bigger time steps and speed up the simulations. One of the advantages using the FDA-NCP is its global convergence. We apply it to two examples. The first one corresponds to a simple non-linear parabolic partial differential equation, which describes oxygen diffusion problem inside one cell. The second one consists of a system of non-linear differential equations which describes in-situ combustion model. Both models are rewritten in the quasi-variational form. The main problem consists in tracking the moving. The numerical results show good agreement when compared to simulation using classical Crank-Nicolson finite difference scheme.

THE STUDY OF THE USE OF AN ARTIFICIAL NEURAL NETWORK TO OPTIMIZE THE NUMERICAL SOLUTION OF LAPLACE EQUATION

OLIVEIRA, Jeferson Diehl de *UNISINOS, Brazil*
SIQUEIRA, Eduardo* *UNISINOS, Brazil*
INDRUSIAK, Maria Luiza Sperb *UNISINOS, Brazil*

Artificial Neural Networks (ANNs) are commonly used in classification problems, forecasting and / or optimization in various areas of computing. Thus, the application of ANNs in problems involving the study of heat conduction in numerical simulations has been expanding in recent years. This paper deals with obtaining the numerical solution of heat conduction with the aid of an ANN in a two-dimensional computational mesh containing fixed boundary temperatures. The main reason for this study is due to the fact that despite the discretization number of Laplace's equation by relaxation deliver compatible solution to this problem, the use of an ANN assists in the generation of starting values for all points contained in the mesh. These values represent the initial conditions at each point of the grid before the application of the method of relaxation. This reduces the number of iterations required for convergence of values at each point by iterative method. To this end the ANN must pass prior to a learning process. This processing technique is of great importance since, after training it is capable of generating results, from the initial data with a single iteration. Preliminary results indicate that the ANN values at each grid point are close to those obtained by solving the Laplace equation. In other situations, the results obtained by ANN converge to those obtained by discretization of the Laplace equation with an accuracy of two decimal places.

A SIMPLEX TYPE METHOD FOR BI-OBJECTIVE OPTIMIZATION

PEACHEY, T. C. *Monash University, Australia*
RILEY, M. J. W.* *Lincoln University, United Kingdom*

For single objective optimization a rich variety of optimization methods have been developed. These include downhill search methods suited to smooth functions of continuous variables. In this category, the simplex method of Nelder and Mead is widely popular as it does not rely on estimates of the gradient and is relatively robust under noise. Much optimization within engineering involves multiple objectives and the determination of Pareto optima for functions of continuous variables. The objective functions are typically smooth in some sense. However there has been little development of downhill search methods for such problems. This paper presents a method similar to the simplex method but applicable to bi-objective searches. The basis for this method is the simple observation that, at an internal Pareto point for a bi-objective optimization, the gradients of the two objective functions face in opposite directions. Thus the search for Pareto points may be reduced to maximizing a single objective, the angle between the two gradients. This is done iteratively using a complex that walks around the search space and then shrinks onto a Pareto point. A by-product of a successful search is an indication of the direction of adjacent Pareto points, enabling tracking of the Pareto curve. We demonstrate the efficacy and efficiency of the method for some standard test functions and for a structural engineering problem. Comparisons are made with other methods currently featured in the literature.

A FREE DERIVATIVE ALGORITHM FOR CONSTRAINED OPTIMIZATION BASED ON MATHEMATICAL PROGRAMMING

CORTES, Henry O. *COPPE/Federal University of Rio de Janeiro,, Brazil*
HERSKOVITS, José* *COPPE/Federal University of Rio de Janeiro,, Brazil*
ARAUJO, Aurélio L. *Technical University of Lisbon, Portugal*
MOTA SOARES, C. M. *Technical University of Lisbon, Portugal*

Constrained optimization problems without derivatives computation are increasingly employed in engineering practice. The two main strategies for working with such problems are the use of derivative free algorithms or the adaptation of gradient based conventional algorithms by derivatives approximation. The poor performance of free derivatives algorithms and their difficulty to respect the design constraints discourages their use in the technical and scientific community. On the other hand, the more used technique to enable conventional algorithms based on the gradient in solving this kind of problems is certainly the use of finite differences, but this technique has a high computational cost and in some cases cannot be applied, as happens in the presence of external noise. With this in mind, this work presents a method for constrained optimization that is based on the Feasible Arc Interior Point Algorithm (FAIPA) and employs derivatives approximation. So, here called FAIPA-AG, allows get feasible solutions keeping the performance of gradient based algorithms, in terms of number of iterations and are robust. Its variant FAIPA-AG-N is presented for the case where there is mild noise in the data. FAIPA is a feasible point quasi-Newton algorithm for smooth nonlinear constrained optimization. Requires an initial point at the interior of the inequality constraints and produces an interior points sequence. The objective function is reduced at each iteration in the case of inequality constrained problems. An appropriate potential function is employed when equalities are considered. FAIPA computes at each iteration a feasible descent arc and performs a line search along this arc that determines a new feasible point with a lower objective. Solid theoretical results and a large numerical experience makes FAIPA an efficient and robust technique for large Engineering applications. The techniques proposed here are used to solve truss structures optimization problems and are compared with two well-known algorithms. Two applications in structures made from laminated composite are addressed, consisting of mechanical properties identification and optimal distribution of piezoelectric actuators. [1] HERSKOVITS J . A Feasible Directions Interior Point Technique For Nonlinear Optimization. JOTA, Journal of Optimization Theory and Applications, London, v. 99, n. 1, p. 121-146, 1998.

Mechanical Engineering – Manufacturing – Machinery

SOLUTION OF CELL MANUFACTURING LAYOUT PROBLEM THROUGH A DISCRETE HYBRID BFOA-GA

MEJIA MONCAYO, Camilo* *National University of Colombia, Colombia*
GARZÓN ALVARADO, Diego Alexander *National University of Colombia, Colombia*
ARROYO OSORIO, José Manuel *National University of Colombia, Colombia*

In this work we present a novel solution of the cell manufacturing layout problem through of a Discrete Hybrid BFOA-GA algorithm (Bacterial Foraging Optimization Algorithm - Genetic Algorithm). The cell manufacturing layout problem include two problems: first the cell formation problem (CF) take a count the similarity between parts with respect to shape and production process to cluster the machines in cells and parts in families. The second problem is the inter and intra cell layout problem, in the which define the relative position of machines into cell and the relative position of cells. The solution proposed has solved simultaneously the two problems, through an objective function that minimize the transport cost and maximizes the cluster of cells, considering the sequence of operations, production volume, quantity of parts in each movement. The Discrete Hybrid BFOA-GA combine the structure of BFOA and GA to exploit the characteristics of two algorithms, GA allow get convergence with the reproduction process and BFOA explore the search space with the chemotactic steps of each bacteria. The performed of this proposal is tested with five benchmark problems and the results are better the single BFOA or GA to this problem.

EXTENDING THE FATIGUE LIFE OF A FUEL VENT HOLE IN AN AIRCRAFT COMPONENT USING SHAPE OPTIMISATION

DAS, Raj* *University of Auckland, NEW ZEALAND*
JONES, Rhys *Monash University, Australia*

This paper investigates the fatigue life optimisation of a Fuel Flow Vent Hole (FFVH) located in the Wing Pivot Fitting (WPF) of an F-111 aircraft assuming a damage tolerance design philosophy. The design of the vent hole shape is undertaken considering the basic durability based design objectives of fatigue life. Damage tolerance based design optimisation is undertaken to determine the shape of the cutout so as to maximise its fatigue life. For fatigue life optimisation, the problem is analysed using the gradient-less Biological algorithm. The optimum shapes of the vent hole are determined considering the fatigue life as the distinct design objectives in the presence of numerous three-dimensional cracks located along the vent hole boundary. A number of crack cases are considered to investigate how the crack size affects the optimal shapes. A semi-analytical method is employed for computation of the stress intensity factors (SIF), and an analytical crack closure model is subsequently used to evaluate the fatigue life. The 3D Biological algorithm is used for designing the cutout profiles that optimise the fatigue life of the component. An improved fatigue life is achieved for the optimal designs. The variability in fatigue life around the cutout boundary is reduced, thereby making the shape more evenly fatigue critical. The vent hole shapes optimised for fatigue life vary with the size of the flaws. This emphasises the need to consider fatigue life as the explicit design objective. The durability based optimal vent hole shapes depend on the initial and final crack sizes. It is also shown that a damage tolerance optimisation additionally produces a reduced weight WPF component, which is

highly desirable for aerospace industries. The design space near the 'optimal' region is found to be flat. This allows us to achieve a considerable enhancement in fatigue performance without precisely identifying the local/global optimum solution, and also enables us to select a reduced weight 'near optimal' design rather than the precise optimal shape.

OPTIMIZATION IN FACE-HOBBED SPIRAL BEVEL GEARS

SIMON, Vilmos V.* *Budapest University of Technology and Economics, Hungary*

In this study, an optimization methodology is proposed to systematically define optimal head-cutter geometry and machine tool settings to simultaneously minimize tooth contact pressures and angular displacement error of the driven gear (the transmission error) of face-hobbed spiral bevel gears, while concurrently confining the loaded contact pattern within the tooth boundaries and avoiding any edge- or corner-contact conditions. The proposed optimization procedure relies heavily on a loaded tooth contact analysis for the prediction of tooth contact pressure distribution and transmission errors. The load distribution and transmission error calculation method employed in this study was developed by the author of this paper. The targeted optimization problem is a nonlinear constrained optimization problem, belonging to the framework of nonlinear programming. In addition, the objective function and the constraints are not available analytically, but they are computable, i.e., they exist numerically through the loaded tooth contact analysis. Therefore, the problem also falls within the category of simultaneous-based optimization. As a consequence, a good deal of numerical noise is introduced into the model, which causes the calculation of partial derivatives for gradient-based optimization algorithms to be quite impractical, even for underlying smooth problems (which is the case under consideration). In this scenario, finite-difference approximation of the gradient can be unreliable. On top of these issues, the typically available loaded tooth contact analysis tools rely on models based on several levels of discretization: Discretization error contributes to the risk of having wildly inaccurate derivative estimates. For all of these reasons, a nonderivative method is selected to solve this particular optimization problem. That is the reason that the core algorithm of the proposed nonlinear programming procedure is based on a direct search method. The Hooke and Jeeves pattern search method is applied. Effectiveness of this optimization was demonstrated by using a face-hobbed spiral bevel gear example. Drastic reductions in the maximum tooth contact pressure (for 64%) and in the transmission errors (for 74%) were obtained. Minimizing the transmission error would certainly entail a reduction in vibratory excitation (hence noise) of the gear drive at its operating conditions.

SOLVING THE NON-LINEAR SLAB STACK SHUFFLING PROBLEM USING LINEAR BINARY INTEGER PROGRAMMING

FERNANDES, Edson Felipe Amado *PUC-Rio, Brazil*
FREIRE, Lucas* *PUC-Rio, Brazil*
PASSOS, Aderson Campos *PUC-Rio, Brazil*
STREET, Alexandre *PUC-Rio, Brazil*

This work presents the results of a model to solve a typical problem in the steel industry, known as Slab Stack Shuffling (SSS) problem. The originally non-linear problem was linearized through specific modeling techniques and then solved using a linear binary integer programming (BIP) model. The main objective is to choose the optimal sequence of slabs that meets the rolling mill demand, minimizing the number of slabs shuffled in the slab yard. The BIP model was implemented using the Xpress optimization software, and the results were compared with a greed heuristic used in a steel mill in Shangai. Experiments performed in a simulated slab yard generated a reduction of 10% in the number of slabs shuffled.

EXPLORING THE USE OF ADJOINT METHODS FOR DETAILED SENSITIVITY ANALYSIS ON TURBOMACHINERY

MARTA, Andre C.* *Center for Aerospace Science and Technology, Instituto Superior Tecnico, Portugal*
SHANKARAN, Sriram *Global Research Center, General Electric, United States of America*

During the last decade, significant progress has been made in the field of optimization using high-fidelity models. The increased use of adjoint methods has allowed the computation of sensitivity information, required by gradient-based optimizers, in a very efficient manner. In terms of fluid dynamics, while the first applications were focused on aerodynamic shape design, recent approaches to the development of adjoint solvers, namely with the use of automatic differentiation tools, have made possible to extend their capabilities far beyond that. The present paper briefly describes a discrete adjoint method implementation for a generic

CFD solver and lays down the steps to estimate sensitivities of functions of interest with respect to any variables handled by the flow solver. The applications presented are based on turbomachinery blade design problems. Two different capabilities are illustrated: one more traditional geared towards shape optimization, that focuses on estimating gradients of some turbomachinery performance parameters with respect to blade geometry, and another more innovative geared towards estimating the effect of the inlet and exit boundary conditions on the same performance parameters. The adjoint-based sensitivities are benchmarked using finite-differences. The computational cost of this method compared to the popular finite-difference method is quantified, both in terms of CPU time and memory requirements. The detailed sensitivity information retrieved is discussed from a designer perspective. Other possible applications of adjoint methods are listed and their development implications are also described.

NORMAL BOUNDARY INTERSECTION TO SOLVE A MULTI-OBJECTIVE STOCHASTIC OPTIMIZATION OF ROTOR DYNAMICS

LOPEZ, R. H. *UFSC, Brazil*
RITTO, T. G.* *UFRJ, Brazil*
SAMPAIO, Rubens *PUC-Rio, Brazil*
SOUZA DE CURSI, J. E. *INSA-Rouen, France*

The aim of this work is to pursue the multiobjective optimization of rotor bearing systems considering uncertainties. The two objective function are the mean and variance of the variable of interest. If the weighted sum strategy is applied, the points of the Pareto front get concentrated in certain regions. To overcome this problem, the normal boundary intersection (NBI) approach is employed to decompose the Pareto front into a set of scalar optimization subproblems. However, these subproblems are non-convex and an optimization algorithm is proposed to tackle this issue. The results demonstrated the ability of the proposed method to deal with non-convex multiobjective problems. The goal of the optimization problem is to find the values of a set of parameters ({e.g.} stiffness of the bearing, diameter, mass) for which the natural frequencies of the system are as far away as possible from the rotational speeds of the machine. For this purpose, the Campbell diagram is used and penalty functions are introduced to penalize natural frequencies close to the rotational speeds of the machine.

MULTIOBJETIVE OPTIMIZATION BASED ON MULTIPHYSICS MODELS OF HIGH FREQUENCY ELECTRIC RESISTANCE WELDING PROCESS FOR PIPES MANUFACTURE

CHERIONI, Diego Ariel* *UTN-FRC, Argentina*
KARHAN, Luis Guillermo *UTN-FRC, Argentina*
HOYA SÁNCHEZ, Roberto A. *UTN-FRC, Argentina*
LANZETTI, Diego Lucas *UTN-FRC, Argentina*
COGGIOLA, Mauricio Celestino *UTN-FRC, Argentina*
GARRERA, Raúl *UTN-FRC, Argentina*

In this paper, mathematical models of coupled physics of the High Frequency Electric Resistance Welding (HF-ERW) process for welded pipes manufacture are proposed to determine its optimal process parameters. The Joule Heating stage (thermo-electric phenomenon) and the forging stage (themo-mechanic phenomenon) of the strip edges and the heat treatment (phenomenon of thermo-microestructural evolution) of the Heat-Affected Zone (HAZ) are included in the process models. Time and space dependences of parameters and variables are also considered in the models, since of particular process characteristics like skin effect, proximity effect and peak effect of high frequency current in strip edges are important issues. In addition, great changes of material states during the process make variations in its properties, and that condition the quality and stability of each process stage, thus physics models are coupled in the modeling approach. The systems models are treated by modified Galerkin's finite element methods, and are implemented and validated by MATLAB v. 7.6 and its modeling and optimizing tools. The coupling variables are solved by algorithms based on calculated state variables and groups of experimental values of each physical coefficient concerned. A sensibility analysis is presented, which showed that initial electrical current density, conformation pipe velocity, wall thickness of pipe and heat treatment time have great impact in the welding quality. Finally, multi-objective optimization based on process models is presented like a functional tactic to set the optimal process conditions.

SENSITIVITY ANALYSIS OF THE MECHANICAL PARAMETERS OF THE SHEET METALS - A TOOL TO PREDICT THE FORMING LIMIT BAND

DRAGOS, George Sven *Technical University of Cluj Napoca, Romania*
BANABIC, Dorel* *Technical University of Cluj Napoca, Romania*

The paper presents a quantitative analysis referring to the variability of the uniaxial and biaxial parameters describing the plastic anisotropy and hardening of the DC01 steel sheets and the influence of this variability on the results on the prediction of the Forming Limit Curves. The influence of the variability of the mechanical parameters on the yield surface predicted by using the BBC 2005 model, developed by the CERTETA team, is also presented. The uniaxial plastic parameters are acquired by means of uniaxial tensile tests performed along three directions in the plane of the sheet metals. The biaxial anisotropy parameters are determined using bulge test (for biaxial yield stress) and disk compression test (for biaxial anisotropy coefficient). Using the FORM-CERT software developed in the CERTETA center, the sensitivity analysis of the different material parameters on the FLC has been studied. The FORM-CERT program implements a computational scheme based on the Hutchinson-Neale model. Using the normal distribution of mechanical properties the plus and minus 3-Sigma limits are used to determine the Upper- and the Lower Forming Limit Curves. The region between these two curves represents the Forming Limit Band. The Forming Limit Band represents a new method to increase the robustness in the simulation of sheet metal forming processes. The Nakazima test has been used to determine experimentally the Forming Limit Curves. The predictions are compared with the experiments. The results presented in the paper are useful for increasing the robustness of the sheet metal forming simulation and thus reducing the risk of defects in production.

EVALUATION BY SIMULATION OF THE MICROSTRUCTURE AND MECHANICAL PROPERTIES IN DUCTILE CAST IRON DUE TO THE ADDITION OF VARIOUS ALLOYING ELEMENTS

SOUZA, Tânia Nogueira Fonseca* *UFMG, Brazil*
AGUILAR, Maria Teresa Paulino *UFMG, Brazil*
NOGUEIRA, Rogéria Alves P.S. *SENAI/CETEF, Brazil*

The Brazilian foundry industry, not different from the others, has used computer simulations as a way of optimizing processes and trying to improve their competitiveness. The competitiveness is also made possible with investment in new alloys exhibit mechanical properties and cost compatible with the new demands. The minor cycles of production, predictability and reliability of performance, has led to a junction of these two factors. It is known that the element presents Niobium Molybdenum with the chemical similarities, and studies have been conducted evaluating the substitution of one another in different alloys. The similarities between the niobium and molybdenum have also been investigated by an artificially intelligent system for classification of chemical elements. This paper shows simulation results obtained by the addition of Molybdenum to the ductile cast iron. The content of Molybdenum was used in the simulation of 0% to 0.8%. The simulation results are compared to experimental data of the addition of Niobium in the same proportions as those applied to Molybdenum. The comparative analysis of the resulting data allows an evaluation of the possibility of substitution of Molybdenum by Niobium in the production of ductile cast iron according to the demands technical and financial feasibility for different projects.

CENTRODE SYNTHESIS FOR A FOUR-BAR MECHANISM.

CABEZAS, Ivan Albeiro* *Universidad Nacional, Colombia*
RODRÍGUEZ, Fernando José *Universidad Nacional de Colombia, Colombia*

In a mechanism, the centrode is the locus of all equal velocity points for a pair of links of a kinematic chain. From the centrode can be obtain a higher pair order joint with the same motion as the original mechanism. Normally, to find the centrode, there is a well known method based on the Kennedy's Theorem. However, for the opposite case, there are not graphical methods or analytical solution. This paper presents a non Grashof planar four-bar linkage synthesis by error minimization and dimensional restrictions.The objective function is proposed and the mechanism is derived. The problem is solved using a SQP algorithm. The solution has been implemented. Examples of typical uses are presented.

KINETIC OPTIMAL WATT DESIGN OF KNEE PROSTHESIS

URREGO, Jorge Andrés* *Universidad Nacional, Colombia*
ORDOÑEZ, Juanita *Universidad Nacional de Colombia, Colombia*
HENAO, Carlos Andres *Universidad Nacional de Colombia, Colombia*
RODRÍGUEZ, Fernando José *Universidad Nacional de Colombia, Colombia*

The most important functional hardware in limb prosthesis is its mechanisms. There are many types of them, include four and six bar mechanism. Efficient prosthesis use embedded electronic systems to control the prosthesis kinematic in response a user natural movement needed. They have a commercial use and there are many people wear that prosthesis. The first thing for a good control is good hardware. Only the idea of the type and topology of a mechanism is no enough. It is necessary to obtain an optimal design based on patient needs and minimal performance demands. This paper presents the first phase of a knee prosthesis design in progress. This involves the optimization of the mechanism of six bars based on Watt mechanism. The objective function focus in minimize the net force on all of its six joints while the desire movement is preserved. To solve, Sequential Quadratic Programming was used. Using the results, a prototype was made.

ROBUST INVERSE DESIGN OF AIRFOILS AND TURBOMACHINERY CASCADES

MANZANARES-FILHO, Nelson* *Universidade Federal de Itajubá, Brazil*
ANTÔNIO MARCOS GONÇALVES DE, Lima *Universidade Federal de Uberlândia, Brazil*

In the classical design of airfoils and turbomachinery cascades, uncertainties in the geometry originated from manufacturing errors, natural wear, or material deposition may significantly affect their performance which can compromise the normal use of the equipment during its lifetime. In this context, the concept of robustness associated to parameter variations is an important aspect to be investigated in aerodynamic design problems. Moreover, if one considers the parametric optimization of a cascade and airfoil with the aim of maximizing their performance, the uncertainties must be considered, which enable us to identify the confidence regions associated to the robust-optimal design. In the present paper, a robust-optimal inverse design methodology for airfoils and cascades is proposed. Its main goal is firstly identify the distributions associated to the uncertainty parameters to be incorporating into vulnerability. The interest in using such optimization technique is to optimize both the original cost functions associated with the performance of the airfoils and the vulnerability functions which consider the dispersions around the uncertainty variables. After presenting the underlying theoretical foundations, the proposed robust design methodology is performed for an airfoil system. Based on the obtained results, the usefulness of the proposed methodology is highlighted.

DAMPING IDENTIFICATION OF MECHANICAL SYSTEMS

SILVA, Bruna Tavares Vieira* *Universidade de Taubaté, Brazil*
SOARES, Álvaro Manoel de Souza *Universidade de Taubaté, Brazil*
GONÇALVES, João Bosco *Universidade de Taubaté, Brazil*

Much research has been done in developing techniques for identifying the structural damping of physical systems. Such techniques are always accompanied by the development of an analytical model of the ideal system and its comparison with experimental data obtained in the laboratory. In this work, are shown techniques for identifying the structural damping of a physical system and its applications in two different physical systems. First we identified the structural damping of a system composed of a simple pendulum and further we mounted a more complex system and identified the damping coefficient of a physical system consisting of a flexible beam clamped, using a mass-spring-damper model. The excitation of both systems was carried out using an impact hammer in order to use such data at the input of analytical models obtained for these systems. For the simple pendulum, was used the logarithmic decrement method for identification of damping factor and for the flexible system, we implemented the methodology of recursive Kalman's filter. The results show that the techniques have been successfully applied as the error obtained by comparing the experimental and analytical data is small.

Oil and Gas Applications

A MIXED-INTEGER NONLINEAR FORMULATION FOR OPTIMAL OPERATION OF OIL FIELDS WITH FACILITY, ROUTING, AND PRESSURE CONSTRAINTS

AGUIAR, Marco Aurelio Schmitz *Federal University of Santa Catarina, Brazil*
SILVA, Thiago Lima *Federal University of Santa Catarina, Brazil*
CAMPONOGARA, Eduardo* *Federal University of Santa Catarina, Brazil*

With the increase of the demand for fossil energy, the oil industry has looked for new technologies in hardware and software to enable production optimization of oil fields. These are evolving technologies often referred to smart fields. Before this concept is transferred to the oil fields, significant challenges in science and technology should be overcome. This paper addresses the problem of optimizing production of complex oil fields operated with artificial lift and subject to facility, routing, and pressure constraints. Large oil fields have several production wells spread over a wide area. The production of clusters of wells is concentrated in manifolds which share a common line connecting the manifold to the separator, where the multiphase flow is split in gas, oil, and water. In such fields, the reservoir internal pressure is not sufficiently high to naturally raise oil to the surface, requiring the use of artificial lift techniques. A common method is gas-lift which injects high-pressure gas at the bottom of the wellbore to reduce the counter pressure and thereby generate oil flow to the surface. In such systems, oil production is a function of the lift-gas injected and pressure at the well head, which is also related to the separator nominal pressure through pressure drops in production lines. Here comes the challenge of modeling the production function and pressure drops in pipelines, which are rather complex and nonconvex. The production optimization problem consists of a mixed-integer nonlinear problem for which standard algorithms cannot be directly applied. The proposed solution approach uses two-dimensional piecewise-linear models for the well production functions depending on lift-gas rate and well-head pressure and continuous convex approximations for the three-dimensional pressure-drop functions. The continuous convex approximations have the advantage of being quite compact when compared to three-dimensional piecewise-linear models. In the end, the production optimization problem is reformulated as a mixed-integer convex program which can be tackled with standard solvers. Computational experiments are performed to compare the mixed-integer convex reformulation and a mixed-integer linear reformulation obtained by piecewise-linearizing the pressure drops, which is more precise but demands a huge number of sample points. The experiments assess the trade-off between solution speed and the degree of approximation across formulations.

AUTOMATIC HISTORY MATCHING CONSIDERING SURROGATE BASED OTPIMIZATION AND KARHUNEN-LOÈVE EXPANSIONS

DE LIRA JR, José Dásio * *UFPE, Brazil*
BASTOS AFONSO, Silvana Maria *Universidade Federal de Pernambuco - UFPE, Brazill*
WILLMERSDORF, Ramiro Brito *UFPE, Brazil*
HOROWITZ, Bernardo *UFPE, Brazil*

The history matching (HM) problem aims to validate and improve the characterization and fluid flow numerical models for an oil field. It is a problem of inversion of production data in order to obtain reliable estimates of physical properties of the reservoir (e.g. porosity, permeability). The most common used method for history matching is to execute many simulations changing a few parameters at a time in a

trial-and-error fashion. This is a very costly and time consuming approach as in general it requires months of effort and many simulations to achieve a good solution, and often may not provide a good predictor of future field performance. Automatic HM can be conducted by optimization techniques, which is in general a more effective way to solve this problem. Given a set of observed data one seeks the physical properties (design variables) values from which, in a general sense, the difference between the observed and calculated response is minimized. In this work, the permeability of the rock reservoir will be the quantity to be adjusted. However, the consideration of the rock properties along every cell of the numerical model that represents the reservoir as design variables would lead to an unfeasible large number of variables and consequently, a very difficult problem to be solved. To overcome that, we will assume that the permeability field will be stochastic and represented by a spectral decomposition through Karhunen-Loève expansion (KLE). In this work both linear and nonlinear forms for KLE expansions will be investigated. Apart from that, HM by optimization techniques commonly involves several calls of the numerical simulator, which may turn the optimization task into a very time consuming process. In order to ameliorate such drawback, surrogate models using Kriging based data fitting will be employed in substitution to the numerical reservoir simulations. The required numerical reservoir simulations to build Kriging models are performed using the IMEX commercial software from Computer modeling group (CMG). Two applications illustrate the use of the presented methodology to conduct the HM of the reservoirs from which synthetic permeability fields created from a given analytic covariance function are used. The results obtained show that our method is able to reconstruct the unknown permeability distribution in a reliable and efficient way from synthetic data provided by a numerical solution.

CONSTRAINTS HANDLING FOR HYBRID ALGORITHMS IN WATERFLOODING OPTIMIZATION PROBLEM

OLIVEIRA, Leonardo Correi* *Universidade Federal de Pernambuco - UFPE, Brazil*
AFONSO, Silvana Maria Bastos *Universidade Federal de Pernambuco - UFPE, Brazil*
HOROWITZ, Bernardo *Universidade Federal de Pernambuco - UFPE, Brazil*
LEMONGE, Afonso Celso de Castro *Universidade Federal de Juiz de Fora - UFJF, Brazil*

In general, the objective in optimization of exploitation problems of a petroleum field is related to the production itself or to an economical design. In oil Reservoir Engineering applications, a problem of great interest is the dynamic optimization of waterflooding management. Considering the economy, profitability is usually chosen as an indicator, and in this work the net present value (NPV) is taken as the function to be maximized. The design variables are the allocated rates at producers and injectors wells. Usually the concession period is subdivided into a number of control cycles, whose switching times are fixed and the well rates are applied. Alternatively, the switching times can be considered as design variables in the optimization formulation problem. This assumption increases flexibility in management and can decreases the total number of variables for similar recovery efficiency. In despite of this, the formulation of this problem leads to a highly nonlinear, multimodal objective function. An adequate choice to solve this problem is to consider a global optimization strategy. Due to the cost of the reservoir analysis and the convergence behavior for this kind of algorithms, a hybrid optimization strategy is proposed considering surrogate models. Surrogates are constructed by a Kriging scheme built from a set of solutions obtained using the simulator on sample points previously generated using the Latinized Centroidal Voronoi Tessellation (LCVT) technique. The hybrid strategy combines different methods at different stages of the process in order to exploit the best features of each methodology. The focus is to balance a global search process with the precision and efficiency of a local search procedure. In such process, the global search is driven by the genetic algorithm (GA) and the local search is driven by the sequential approximation optimization (SAO) method. In general, evolutionary algorithms are suitable to solve unconstrained problems. Techniques to handle the constraints of the waterflooding problem are proposed in this work. Different strategies may be used to include general constraints. Among them it is considered an adaptive penalty method which does not require any type of user defined penalty parameter and uses information from the population. Moreover, to make the global search procedure more effective a filter scheme is proposed in which the level of feasibility of the initial population is assured.

OPTIMAL OPERATION OF A THREE-PHASE SEPARATOR TO MINIMIZE SEVERE SLUGS EFFECTS IN OFFSHORE OIL PLATFORMS

MIYOSHI, Simone de Carvalho* *EQ/UFRJ, Brazil*
MONTE, Thiago *Poli/UFRJ, Brazil*
BENDIA, Rafael Macedo *PEE/COPPE/UFRJ, Brazil*
SOUZA JR., Maurício Bezerra de *EQ/UFRJ, Brazil*
SECCHI, Argimiro R. *PEQ/COPPE/UFRJ, Brazil*

During the exploitation of offshore oil and gas, the produced fluids flow from the formation into the wellbore and then into the tubing and flowlines to finally reach the topside primary processing system. There, these produced fluids are heated and separated into water, gas and oil in a three-phase separator due to the difference of density of each phase. Besides, the separation is also responsible to absorb possible flowing fluctuations from the produced fluids such as intermittent flowing patterns as severe slug. Slugging interfere the levels controls of the three-phase separator. Moreover, this oscillating behavior can be propagated in the downstream processing equipments affecting the separation process and the products specification. In order to reduce these slugging associated problems, this study aims to develop an optimization strategy to minimize the downstream oscillatory behavior maintaining the oil-water interface level and oil level of the three-phase separator under constrained control subject to severe slug. Different objective functions were investigated to attenuate the oscillations provoked by the slugs. The EMSO (Environment for Modeling, Simulation and Optimization) dynamic simulator was used for process simulation and implementation of the regulatory controls (levels and pressure). A multilevel hierarchical control system was applied using a model predictive controller (MPC) from MATLAB's MPC toolbox, designed to actuate on the set-points of the level regulatory controllers. As results, the slugging effects in the outlet flowrates and pressure of the three-phase separator were minimized by manipulating the set-points of the level controllers subject to levels constraints.

PRODUCTION OPTIMIZATION IN OIL PRODUCING WELLS WITH CONTINUOUS GAS LIFT

TEIXEIRA, Alex Furtado* *CENPES/PETROBRAS, Brazil*
SECCHI, Argimiro R. *PEQ/COPPE/UFRJ, Brazil*
BISCAIA JR., Evaristo Chalbaud *PEQ/COPPE/UFRJ, Brazil*

Currently, about 70% of Brazil's oil production comes from wells that produce with the aid of an artificial lift method known as continuous gas lift. The development of an optimization strategy that maximizes the production of these wells subject to the constraints imposed by the platform process plant is extremely important due to gains in scale that it can provide. This paper presents a model for the production optimization problem of a set of wells which produce using continuous gas lift. The decision variables are the gas lift flow rates injected in each producing well. The proposed model considers an economic objective function and constraints in the amount of gas available for gas lift and in the oil, water and gas handling capacity of the platform. An operational objective function is also modeled and the results are compared with those obtained with the economic objective function. The problems are solved applying two different optimization strategies. One solves the optimization model as a NLP problem using a SQP algorithm and the other solves the problem as a MILP problem trying four different piecewise linearization methods and applying the CPLEX solver. A comparison of the results using a set of performance criteria like CPU time and the number of iterations is performed. The results show that a better operational profit is obtained with an economic objective function and the NLP formulation present a better performance than all MILP strategies.

A COMPARATIVE STUDY OF CONSTRAINT-HANDLING METHODOLOGIES APPLIED TO GENETIC ALGORITHM FOR THE OPTIMIZATION OF SUBMARINE PIPELINE ROUTES.

DE LUCENA, Rodrigo Ribeiro* *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*
COUTINHO, Daniel da Costa e Silva *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*
DE LIMA, Beatriz Souza Leite Pires *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*
BAIOCO, Juliana Souza *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*
ALBRECHT, Carl Horst *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*
JACOB, Breno Pinheiro *COPPE/UFRJ – Post-Graduate Institute of the Federal University of Rio de Janeiro, Brazil*

Researchers from Petrobras and LAMCSO/COPPE/UFRJ are currently involved in the development and implementation of an Evolutionary Algorithms based computational tool for the synthesis and optimization of submarine pipeline routes on deep and ultradeep waters. Such tool must rely on an accurate representation of the design practice constraints. In a previous work these constraints were treated by penalty method approaches (standard static and adaptive techniques). This work proposes new constraint and objective function models for route representation; two constraint-handling techniques (stochastic ranking and e-constrained) associated to the Genetic Algorithm meta-heuristic are implemented on the route optimization tool. Case studies are presented to compare the performance of these methodologies for the treatment of constraints.

REFINING STRUCTURES OPTIMIZATION

BELTRAN MARIN, Miguel Angel* *Universidad Industrial de Santander, Colombia*
KAFAROV, Viatcheslav *Universidad Industrial de Santander, Colombia*
MAHECHA BOHORQUEZ, Cesar Augusto *ECOPETROL S.A., Colombia*

Optimization techniques applied to the oil industry have been developed at different levels of design, planning and scheduling, and at different scales (macro, meso and micro scale). These techniques deal with environmental approaches , product performance and energetic analysis. Moreover address to several approaches from an economic perspective, since their goal could be maximization of profits, net present value, IRR (Internal Rate Revenue), and minimization of different costs types. To achieve this goal, different programming techniques are used, including mixed integer linear programming (MILP), mixed integer nonlinear programming (MINLP), generalized disjunctive programming (GDP), Benders' decomposition, and cutting-plane method, and so on. In order to compile the main financial criteria used in literature on refining structures optimization, this paper discusses different financial criteria used at macro scale for design and planning. It could be applied on further works focused on selecting alternative investment in petrochemical refining structures.

SCHEDULING OF OFFSHORE WELLS ACTIVITIES IN PETROLEUM SPECIFIC RESOURCES

NISHIOKA, Gilberto Koji* *Department of Chemical Engineering - University of São Paulo, Brazil*
JOLY, Marcel *PETROBRAS S/A, Brazil*
LE ROUX, Galo Antonio Carrillo *Department of Chemical Engineering - University of São Paulo, Brazil*

Since the economic viability of an offshore well has been proven, starting its oil production requires execution of some activities on it. Because of the number of wells activities and resources to be considered in a real-world situation, Operations Research techniques emerge as a valuable tool to construct an appropriate scheduling. The problem can be compared to the classical Job Shop Problem (JSP), which deals with the allocation of a set of task into a set of machines, where each task consists of a set of operations and each operation requires the use of one of the machines available. If we consider that each well is a task from a JSP, and the activities in each well are your operations, it is noted that solving the JSP also solves this scheduling problem. Typical constraints considered in this scheduling problem are: (1) once started an activity, it can not be interrupted until its completion; (2) a resource executes only one activity at a time; (3) an activity is performed by a single resource; (4) activities of the same well can only be executed one at a time; (5) the resource must be compatible with the characteristics of the activity; (6) precedences between activities must be obeyed; (7) the activities must be performed within given time window; (8) should be considered a time shift of resources between wells. The aim of this study is to mathematically model the problem using different mixed-integer programming-based solution approaches, and comparing and analyzing the performance of these models in several data instances.

APPLICATION OF PSO ALGORITHM IN SUBMARINE PIPELINE ROUTES OPTIMIZATION

ALBRECHT, Carl Horst* *Universidade Federal do Rio de Janreiro, Brazil*
MONTEIRO, Bruno da Fonseca *Universidade Federal do Rio de Janeiro, Brazil*
BAIOCO, Juliana Souza *Universidade Federal do Rio de Janeiro, Brazil*
LIMA JR, Mauro Henrique Alves de *Universidade Federal do Rio de Janeiro, Brazil*
LIMA, Beatriz Souza Leite Pires de *Universidade Federal do Rio de Janeiro, Brazil*
JACOB, Breno Pinheiro *Universidade Federal do Rio de Janeiro, Brazil*

This work proposes a method to optimize a submarine pipeline route using Particle Swarm Optimization (PSO) algorithm. The main objective (fitness function) is to reach the shortest route between two points, taking into account several aspects of pipelines design. Geophysical and geotechnical data from bathymetry and sonography, definition of obstacles and regions to be avoided as well as other aspects related to the structural behavior of the pipe were taken into consideration. Examples are shown to corroborate the effectiveness of the method.

DECISION SUPPORT SYSTEM FOR OPTIMIZING OILFIELD OPERATIONS

PLUCENIO, Agustinho* *UFSC, Brazil*
CAMPONOGARA, Eduardo *UFSC, Brazil*
GIULIANI, Caio *UFSC, Brazil*
COSTA, Rafael C. D. *UFSC, Brazil*
MEJIA, Rodrigo I. G. *UFSC, Brazil*
NAKASHIMA, Paulo *UFSC, Brazil*

When an oil company on the upstream sector discovers a new oilfield it faces the challenge of designing its exploitation in the most economical way. Part of the process is the assessment of the existent infra-structure installations that can be used to flow the new production. This includes pipelines, pumping units, primary treatment units, etc. In general the capacities of the pipelines and processing units become progressively superior to the demand as the fields under development decrease the production. In this complex scenario it is vital the utilization of mathematical methods that will help to implement the best ways to produce the new field. This happens mainly due to the several constraints that arise when existent installations are reused totally or partially. There are limits on maximum pressures on the pipelines, on maximum water, oil or gas flow-rates related with the capacities of the primary treatment units available. Limits on CO_2 or C_3+, H_2S, etc., may appear related with environment rules and capacities of the treatment units. We present a software being developed in a partnership DAS-UFSC-CENPES-Petrobras which can simulate the main elements of an oil production system and incorporates access to other simulators. Built in the simulator is an interface that allows the fast generation of data to be used in optimization solvers. The software is intended to be an environment to study optimizations and control solutions to different scenarios. The idea is to start with simplified models that exhibit the main system behavior in order to test initial ideas on optimization or control strategies. As these solutions progress more elaborated and representative models can be used by connecting to other existent simulation packages or eventually using improve internal models. The paper presents the utilization of the software with examples using known optimization solvers.

Optimization & Surrogates

COMPARISON BETWEEN RBF AND KRIGING SURROGATES IN DESIGN OPTIMIZATION OF HIGH DIMENSIONAL PROBLEMS

ELSAYED, Khairy *Vrije Universiteit Brussel, Belgium*
VUCINIC, Dean* *Vrije Universiteit Brussel, Belgium*
LACOR, Chris *Vrije Universiteit Brussel, Belgium*
D'IPPOLITO, Roberto *NOESIS Solutions, Belgium*

In this paper, we compare two meta-modeling techniques, Radial basis function neural networks and Kriging, in different aspects such as accuracy, robustness, efficiency, and scalability with the aim to identify advantages and disadvantages of each meta-modeling technique in order to select the most suitable one to be combined with the optimization algorithms. The two surrogate models were constructed using OPTIMUS software based on experimental data set for gas cyclones. The evolutionary genetic algorithm is applied to find the optimum design based on each of the surrogates for single objective optimization. The structure of the various models was investigated and the main differences were addressed. For the cases investigated in this work, kriging surrogate for multi-dimensional problems based on exponential correlation produced a relatively better prediction of new points in the design space and, consequently, better optimized design than the RBF model. The obtained optimum design of cyclone separator for unconstrained problem is followed by CFD simulations to compare the new cyclone design with the standard high efficiency Stairmand design. The CFD simulations results in superior performance of the new design.

ADAPTIVE MULTILEVEL RADIAL BASIS FUNCTION METAMODEL FOR ENGINEERING OPTIMIZATION

MAKIN, Thomas* *University of Bath, United Kingdom*
KIM, H. Alicia *University of Bath, United Kingdom*

Metamodelling in engineering is typically used to replace highly expensive analyses or simulations. This is particularly relevant in the design optimization context where an analysis is required at every iteration as the design is modified and optimized. However, engineering design space with multiple responses and a range of constraints can be highly complex and discontinuous, and this can present challenges for stability and convergence of metamodelling methods. Metamodelling formulations can be broadly categorized to two approaches: global and local. A global approach aims to approximate the entire design space with a single model created using all available data points, whereas a local approach will generally subdivide the design space and construct multiple approximations for local regions of interest. A local model can provide a lightweight high fidelity approximation for a particularly variable region and can be a fast adaptive method for optimization. Global approaches are able to capture larger trends across the design space but can be locally inaccurate and are often not naturally adaptive as stability cannot be guaranteed when new data is added. This paper presents an adaptive multi-level RBF metamodel formulation which combines the advantages of the global and local metamodels. It makes use of all available data but sorts points into a series of levels to ensure the model's stability and convergence. The method employs a compact Radial Basis Function (RBF) formulation with the 'width' of the basis functions successively reducing for each of the model levels. Each level interpolates the residual error from the previous level until a suitable degree of accuracy has been achieved. This ensures a well-conditioned and convergent numerical scheme and allows

for efficient implementation with the potential for parallelization. The multi-level nature of the formulation is used to define local trust regions which provide a test for local model convergence and control the addition of new data points. In this paper the multilevel RBF metamodel is applied to structural optimisation design problems where the local adaptivity is guided by an external optimiser. The behaviour of the model in this context will be investigated and numerical stability of the technique will be demonstrated.

SENSITIVITY AND ROBUSTNESS ASPECTS IN FOCUSED ULTRASONIC THERAPY SIMULATION

BORSOTTO, Dominik *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
CLEES, Tanja *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
NIKITIN, Igor* *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
NIKITINA, Lialia *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
STEFFES-LAI, Daniela *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
THOLE, Clemens-August *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*

Focused ultrasound in combination with magnetic resonance tomography is well established method for non-invasive tumor therapy. The image data serve for specification of tumor volume and healthy organs. Then the energy is selectively injected into the tissue via acoustic waves leading to the destruction of tumor cells. For successful therapy planning numerical simulation is used based on experimentally validated physical models for non-linear wave propagation, absorption in soft tissue, heat transfer, hierarchical structure of biological materials. The major purpose of therapy planning is to adjust treatment parameters, such as position of focal point and intensity of ultrasound, to achieve simultaneously maximal level of tumor destruction and minimal influence to the healthy organs. For this purpose multi-objective optimization is used combined with metamodeling of numerical simulation results. Inherent uncertainties of numerical model are taken into account such as variation of biomechanical properties of the tissues, positioning of the patient, displacement and deformation of organs due to breathing process. A realistic application case is used to demonstrate efficiency of the approach. 208 MRT images are used to compute motion vector fields characterizing breathing process. These fields together with given uncertainties for 27 material parameters have been used in sensitivity analysis. The analysis has been applied to the results of focused ultrasonic simulation with 10 seconds of exposure time. 68% confidence intervals for the resulting thermal doses inside and outside therapy region have been determined enabling robust multi-objective optimization in therapy planning.

THE ASYMPTOTIC BEHAVIOUR OF THE GAUSSIAN CORRELATION FUNCTION IN KRIGING RESPONSE SURFACES

KOK, Schalk* *CSIR, South Africa*

Kriging is a statistical data interpolation method that is used to construct response surfaces for use in Multidisciplinary Design Optimization (MDO). One of the key ingredients in Kriging is the choice of correlation function, and the Gaussian function is one of the more popular choices. The chosen correlation function has adjustable hyper-parameters, which are usually determined using Maximum Likelihood Estimation (MLE). In some cases, the difficulty in solving the optimization problem to determine the hyper-parameters becomes more problematic than solving the original MDO problem. The hyper-parameter optimization problem usually becomes difficult to solve when the MLE function becoming monotonic. In such a case, the MLE function returns hyper-parameters that either approaches zero or infinity. In this paper the asymptotic behaviour of the MLE function, using the Gaussian correlation function, is investigated for several problems. The case where hyper-parameters approach zero is particularly difficult, since this always coincides with the condition number of the correlation matrix approaching infinity. It will be demonstrated that using finite precision computation, a spurious global minimum appears in some problems when in fact the MLE function decreases monotonically as the hyper-parameters decrease to zero (using arbitrary precision computations). This finding is of particular interest, since it contradicts a recent publication that claims that the MLE function always approaches infinity as the hyper-parameters approach zero. This contradiction is resolved by illustrating that the assumptions required by the analytical proof are not valid for some problems. The benefits of allowing as small as possible hyper-parameters (to just prevent ill-conditioning) in this case is also demonstrated. The case where hyper-parameters approach infinity is easier to resolve. In all problems investigated, this merely indicates that insufficient data is available to reliably

estimate a length-scale. Adding data points to an MLE function that monotonically decreases as the hyper-parameters approach infinity, usually introduces a local minimum into the MLE function.

PRACTICAL GUIDELINES TO AVOID ILL-CONDITIONING OF THE CORRELATION MATRIX IN KRIGING RESPONSE SURFACES.

HAARHOFF, Lukas Johannes* *Powertech Transformers, South Africa*
KOK, Schalk *Council for Scientific and Industrial Research, South Africa*
WILKE, Daniel N. *University of Pretoria, South Africa*

Kriging is a Response surface method used in Multidisciplinary Design Optimization (MDO). However, many have reported problems with ill-conditioning of the correlation matrix, a key component in the mathematics of the Kriging method. When the correlation matrix is ill-conditioned it will cause problems with finding the optimum Kriging surface, and will result in inaccurate predictions when using the Kriging surface. The goal of this work is to provide practical guidelines for the choice of the correlation function and the Design Of Experiment (DOE) to use in order to avoid ill-conditioning of the correlation matrix. First, a fair method is proposed to compare the ill-condition behaviour of different cases. Then a modified version of the Gaussian correlation function, a popular choice for the creation of the correlation matrix, is investigated as to the effect of the modification on the known tendency towards ill-conditioning of this correlation function. Other correlation functions, namely the exponential, cubic spline, Matern linear and Matern cubic are then also tested. This is done for different DOEs, specifically the full factorial and Latin Hypercube methods with a range of number of samples. From the results conclusions are drawn as to which correlation function and DOE to use to avoid ill-conditioning.

Pattern Recognition and Image – Signal Processing

COMPUTER VISION APPLIED TO RECOGNITION BARCODE

ALMEIDA, Marcelo de Araújo* *UNITAU - Universidade de Taubaté, Brazil*
SOARES, Álvaro Manoel de Souza *UNITAU - Universidade de Taubaté, Brazil*

The bar code is one of identification technologies used more successfully in the world. This technology was first developed from the second half of the twentieth century and quickly achieved acceptance in both industry and commerce. The wide dissemination of barcodes also created some problems of inappropriate use of materials such as polished metals for example. "The interest in methods of digital image processing comes from two main areas of application: improvement of visual information for human interpretation and processing of image data for storage, transmission and representation, considering the perception by automatic machines" (GONZALEZ and WOODS). Based on this concept this research proposal is the development of an image recognition system for decoding barcodes using techniques of digital image processing and pattern recognition, producing an efficient and open for use in any area where the recognition codes by means of conventional equipment presents difficulties.

OPTIMIZATION OF SIGNAL-TO-NOISE RATIO IN CDTE RADIATION DETECTORS

ANDREEV, Alexey* *Brno University of Technology, Czech Republic*
SIK, Ondrej *Brno University of Technology, Czech Republic*
GRMELA, Lubomir *Brno University of Technology, Czech Republic*

The main application of CdTe in the last years is in high resolution detection of gamma-rays and X-rays. The large band-gap energy allows operating CdTe detectors at room temperature. CdTe detectors have much higher efficiency than Ge and Si detectors and even a detector with a thickness of 0.5 mm provides good detection efficiency for gamma-rays. Despite an extensive effort in the last period crystal quality remains a challenging issue. One of the key problems is a presence of uncontrolled impurities, native defects and their precipitates having deep energy levels. These levels act as recombination and trapping levels causing decrease of charge collection efficiency. Another important problem is contact quality. Au is the common material used for contacting CdTe and because of the difference in work function of CdTe and Au there are identical barriers at the metal-semiconductor junctions. With an applied external voltage to the sample one of the contacts operates in forward bias and another one operates in the reverse bias increasing the width of the depleted region at the contact. The analysis of low frequency noise showed that the experimental value of 1/f noise is always much higher than the theoretical value which corresponds to the total quantity of free carriers in the sample. Free carriers are distributed uniformly throughout the homogenous part of the sample. But within the depleted region there is very low concentration of free carriers which increases exponentially in the direction from the contact area to the homogenous part of the sample. The voltage noise spectral density of 1/f noise is directly proportional to the depleted region width. This depleted region at the contact area is the source of excess value of low frequency noise which is caused by the low carrier concentration within this region. Excess value of low frequency noise leads to deterioration of signal-to-noise ratio. This paper studies the effect of depleted region on transport characteristics of CdTe and on signal-to-noise ratio. One of the ways in optimizing signal-to-noise ratio is to decrease depleted region width. This can be done for example by choosing another material for contacts which has fork function close to the one of CdTe.

Planning and Scheduling

OPTIMIZING THE PERFORMANCE OF MULTISTAGE PROCESS SYSTEMS

HADJINICOLA, George C.* *University of Cyprus, CYPRUS*
SOTERIOU, Andreas C. *University of Cyprus, CYPRUS*

Most products are manufactured in multistage production systems following a production sequence that depends on the nature of the product, the machines available, and the factory layout. Value is added at every production stage until the product is completed. Production sequences in multistage systems can resemble a tree structure or a line, in which case we refer to such systems as serial production systems. Such systems are common in many industries, including semiconductor, chemical, and food industries. In multistage systems, yield losses are inevitable due to a number of reasons such as, machine and material failures during the production process, human error, and the production of new products that the organization has no prior experience. Yield losses due to process imperfections result in cost increases due to the scrapping of the entire product, scrapping of components, and any rework required. We present a modeling framework that assists management to allocate capital resources to improve the yield and the yield variability in a multistage production system. We examine and compare two scenarios for improving the performance of the production system, a budget constrained case and the unconstrained case. Production stages with low yield and/or high yield variability receive more capital resources for improvement. The applicability of the model is demonstrated in a real-life manufacturing firm in the food-packing industry. The solution of the model provides directions of improving the stages of a multistage production system. The modeling framework has the following characteristics: (1) it includes the variance of the yield in each production stage in the allocation of resources for yield improvement, (2) it treats the families of products and their production volumes differently and avoid the aggregation of all products in a single family, (3) it examines and compare two scenarios for improving the performance of the production system, a budget constrained case and the unconstrained case, and (4) it shows how yield and its respective yield variability can be improved simultaneously.

OPTIMIZING TRIPS OF DYNAMIC POSITIONED SHUTTLE TANKERS BETWEEN FPSOS AND ONSHORE FACILITIES

PLUCENIO, Agustinho* *UFSC, Brazil*
CAMPONOGARA, Eduardo *UFSC, Brazil*
PEREIRA, Fernando *UFSC, Brazil*
NAKASHIMA, Paulo *UFSC, Brazil*

In a typical deep water offshore oil exploration the oil produced by a group of wells is accumulated in FPSOs (Floating Production Storage and Off-loading Units). To transfer the oil from the FPSOs to the tanker ships the oil must first be offloaded and transported to a transfer terminal using special vessels named dynamic positioned tankers (DPTs). For a large number of FPSOs a fleet of DPTs is required and the scheduling of DPT trips among terminal and FPSOs should be optimized. DPT capacities, FPSO capacities and daily flow-rates, minimum FPSOs storage volume, and minimum volume to be offloaded from the FPSOs, among other restrictions, play an important role in the decision. One can look to the problem as a business case. The time an amount of oil is left in a FPSO means a loss of revenue due to the tax lost on the money equivalent. In other words, the oil owner would have to pay a certain tax to have the money that is left in the FPSO in the form of oil. On the other hand there is a cost to bring the oil to the terminal. This cost is related to the DPT rentals and operations. But, much more important than the DPT scheduling optimization, is the need to keep the FPSO with sufficiently high storage capacity to keep wells producting. Should a FPSO reach its storage capacity, the wells would have to be shut what is not acceptable. Therefore the optimization algorithm must be tailored in order to primarily ensure a proper offloading of the FPSOs. The overall optimization strategy consists in defining a future time window of length T over which an optimization algorithm is run every day. The algorithm determines all the moves to be performed during the time window but only the decisions of the first day are implemented and the algorithm is run again following a sliding horizon strategy similar to what is done in model predictive control techniques. This document describes the formulation of the optimization problem to be solved within the time window. The problem is solved using a Mixed Integer Linear Programming Technique and the results of a simulated instantiation example are presented.

TRANSPORTATION COST X ECONOMIC LOT

REZENDE FILHO, Mauro* *Universidade Gama Filho*, *Brazil*
CRUZ, Amaury Bordallo *Universidade Gama Filho*, *Brazil*
BENZECRY, José Haim *Universidade Gama Filho*, *Brazil*
RIBEIRO DE ALMEIDA, Marco Antonio *Universidade Gama Filho*, *Brazil*

With the current globalization of world economy, the optimization of financial resources makes the cost reduction one of the main goals to be reached without compromising the activity of the company. The investment in stock, the storage cost, the cost of orders and the cost with transportation, are the items which affect in a significant way the rentability of a company. It then becomes important the need of studying the influence of the transportation in the calculation formula of the economic purchasing lot. The relevance of this study is to add the transportation cost to the operational cost of keeping stocks, given the fiscal principals. In this way, this work is destinated to the development of a new formula for the economic lot calculation of purchasing with the inclusion of the variable of the transportation and also to the identification of the lowest operational cost through simulations in spreadsheets and the use of linear programming.

SEQUENCING ACTIVITIES IN A PROJECT NETWORK CONSIDERING RESOURCE COMPLEMENTARITY

SILVA, Helder Cruz* *IFAM-Federal Institute of Education, Science and Technology Amazonas*, *Brazil*
TERESO, Anabela Pereira *University of Minho*, *Portugal*
OLIVEIRA, José António *University of Minho*, *Portugal*

The methodology of project management has been widespread in organizations of different functions and sizes. In this context, we address the issue of optimal resource allocation, and more specifically, the analysis of complementarity of resources (primary resource and supportive resource) in a project. The concept of complementarity, which has been discussed based on an economic view, can be incorporated into the engineering domain as an enhancement of the efficacy of a "primary" resource (P-resource) by adding to it another "supportive" resource (S-resource). No replacement takes place. The gain achieved from such action is manifested in improved performance; e.g., shorter duration or improved quality, because of the enhanced performance of the P-resource. But such gain is usually achieved at an increased cost; namely the cost of the support resource(s). We developed a conceptual system capable of determining the ideal timing, and the ideal mixture of resources allocated to the activities of a project, such that the project is completed on time, if not earlier, with minimal cost. In this paper we present new computational results of a Genetic Algorithm, based in a random keys alphabet to optimize the process to reach better result.

A GENERAL VARIABLE NEIGHBORHOOD SEARCH HEURISTIC FOR THE SINGLE VEHICLE ROUTING PROBLEM WITH DELIVERIES AND SELECTIVE PICKUPS

COELHO, Igor Machado *Fluminense Federal University*, *Brazil*
OCHI, Luiz Satoru *Fluminense Federal University*, *Brazil*
SOUZA, Marcone Jamilson Freitas *Federal University of Ouro Preto*, *Brazil*
HADDAD, Matheus Nohra *Fluminense Federal University*, *Brazil*

This work addresses the Single Vehicle Routing Problem with Deliveries and Selective Pickups (SVRPDSP). In this problem deliveries have to be made to a set of customers, but there are also pickup goods to be

collected depending on the revenue generated by them. Practical applications arise in a number of reverse logistics contexts in which customers return goods back to the depot, as in postal logistics. The SVRPDSP belongs to the NP-hard class, once it can be reduced to the classic Traveling Salesman Problem when there aren't any pickups to be made. To solve this problem, we propose a hybrid heuristic algorithm, named HGVNS, inpired on the metaheuristic General Variable Neighborhood Search combined with an initial solution generation by means of exact methods. The proposed algorithm was tested with a set of instances available in literature and showed to be efficient in the resolution of the problem at hand, since it overcomes the best known algorithm in literature.

CUTSET INEQUALITIES FOR ROBUST NETWORK DESIGN

RAACK, Christian* *Zuse Institute Berlin, Germany*

In order to create and operate resource- and cost-efficient telecommunication or public transport networks the uncertainty of traffic demand (data or passengers) has to be taken into account already in the strategic capacity design process. A promising approach is to apply methodologies from robust optimization, that is, to assume that all realistic demand scenarios lie in a predefined convex uncertainty set. A capacity design is said to be feasible if it supports all scenarios from this set. Deterministic network design problems can be solved using multi-commodity-flow formulations. The corresponding link capacity and cost models typically reflect practical requirements such as the installation of capacities in discrete batches or the selection of admissible configurations from a discrete set. It is known that the resulting Mixed Integer Programming (MIP) models can be improved by adding strong valid inequalities based on network cuts, so-called cutset inequalities. In fact, this may lead to a significant speed-up in the solution process. In this work, combining methods from Robust Optimization and Mixed Integer Programming, we study the impact of cutset inequalities in solving robust network design problems. We assume that traffic demands are given as a polyhedral set, e.g. following the well-known hose-model based on node traffic bounds. We present facet proofs for different variants of these inequalities in different variable spaces thereby generalizing the deterministic single scenario case. It is shown that robust cutset inequalities are independent of the chosen recourse scheme (static or dynamic routing). We also report on computational tests showing a significant speed-up when augmenting standard solvers such as CPLEX with cutting planes based on network cuts in a tailored branch-and-cut framework.

Process Optimization and Equipment

IMPLEMENTATION OF PARETO MULTIOBJECTIVE PARTICLE SWARM OPTIMIZATION ALGORITHM IN EMSO

GONÇALES, L. C. G. *UFSCAR, Brazil*
FURLAN, F. F. *UFSCAR, Brazil*
SOARES, R. P. *UFRGS, Brazil*
SECCHI, Argimiro R. *UFRJ, Brazil*
GIORDANO, R. C. *UFSCAR, Brazil*
COSTA, C. B. B.* *UFSCAR, Brazil*

EMSO, Environment for Modeling Simulation and Optimization, is a free brazilian equation-oriented process simulator, which began to be developed in 2001. It is entirely written in C++ and supports chemical processes simulation (both static and dynamic), static optimization and parameter estimation. Nevertheless, only mono-objective optimization was possible. This work presents the implementation of a multiobjective particle swarm optimization (MOPSO) algorithm in EMSO, in order to deal with multiobjective optimization problems. The algorithm originally proposed by Raquel and Naval (An effective use of crowding distance in multiobjective particle swarm optimization. In Proceedings of the Genetic and Evolutionary Computation Conference, 257-264, 2005) was selected to be implemented due to the success in finding true Pareto Front solutions in mathematical benchmark multiobjetctive optimization problems. The MOPSO code was implemented as a shared library and included in EMSO. Both mathematical and engineering multiobjective optimization problems were considered. In this study, the implementation and application of MOPSO in ammonia production process is presented. Pareto fronts generated by MOPSO and the exploration capabilities of the algorithm are discussed.

EVALUATION OF FEASIBLE AND INFEASIBLE PATH TECHNIQUES FOR PROCESS OPTIMIZATION COUPLED TO AN EQUATION-ORIENTED PROCESS SIMULATOR

CAMPOS, Rafael Barbosa* *Programa de Engenharia Química - COPPE - Universidade Federal do Rio de Janeiro, Brazil*
ORENSTEIN, Leonardo P. *Programa de Engenharia Química - COPPE - Universidade Federal do Rio de Janeiro, Brazil*
SECCHI, Argimiro R. *Programa de Engenharia Química - COPPE - Universidade Federal do Rio de Janeiro, Brazil*
BISCAIA JR., Evaristo Chalbaud *Programa de Engenharia Química - COPPE - Universidade Federal do Rio de Janeiro, Brazil*

Process optimization is one of the main quantitative tools in industrial decision making, because a variety of problems in design, operation, analysis and control of chemical plants (as well as many other industrial processes) can be solved through optimization. The main challenge in using these tools is how to robustly integrate them to process simulators without losing their performance. In this work, a comparative analysis of feasible and infeasible path techniques for process optimization coupled to an equation-oriented process simulator is carried out. In the feasible path technique, the decision variables are only a subset of the simulator specified variables that has a solution satisfying the process model equations at each optimizer's iteration. In the infeasible path technique, the decision variables are all problem variables and a feasible solution is guaranteed only after the convergence of the optimizer. Several well-studied benchmarks of process optimization from literature, especially from Edgar et al. (2001) and Koziel & Michalewicz (1999), were implemented and solved in the EMSO process simulator – Environment for Modeling, Simulation and Optimization (Soares & Secchi, 2003) – in order to establish comparison criteria (such as robustness,

number of objective function evaluations, etc..) among the used methods. The solver chosen for solving the optimization problems and establish a metric to compare the two techniques, IPOPT - Internal Point Optimizer (Wächter & Biegler, 2006), is an open-source software package for large-scale nonlinear optimization that implements an interior point line search filter method. The selected examples have different characteristics such as size of optimization problem, nonlinearity, non-convexity, number of inequality constraints, type of objective function and sensitivity to initial estimates. Preliminary results have shown that, particularly in problems with large numbers of variables and equations, the feasible path optimization technique show better or equal results than the infeasible path technique although the computational effort and execution time is significantly higher.

PULP FIBRES REFINING OPTIMIZATION: A STUDY FOR ENERGY CONSUMPTION MINIMIZATION AND CONJUGATE PAPER PROPERTIES OPTIMIZATION

VAZ, Álvaro Frederico* *Universidade da Beira Interior - Covilhã, Portugal*
SIMÕES, Rogério Manuel *Universidade de Beira Interior, Portugal*
SILVY, Jacques *Universidade da Beira Interior, Portugal*

The primary goal of this work was to set up a methodology to establish a relationship between pulp properties, namely morphological and physical, and paper properties, specifically structural, optical and strength, with the operating variables of refining and the physical and chemical properties of the raw material. The specific goals were to contribute to the analysis of the beatability of chemical pulps for paper production, the conjugated properties optimization and energy consumption minimization. Three chemical pulps with different average morphological characteristics were used, obtained from Pinus sylvestris, Eucalyptus globulus and Betula verrucosa. The final objective was to establish the chemical pulps refining efficiency parameters for energy savings in paper production. In order to obtain that, the refining hydromechanics and energetic consumption profile was analysed for the different pulps. So, the normal and tangential forces exerted on the pulp suspension in the gap clearance were evaluated, the distance between rotor and stator was measured and power consumption in no-load and refining conditions were calculated. The refining essays took place in a laboratory Valley beater, and the studied variables were the charge on the roll, the rotor speed of rotation and the specific applied energy. In terms of the first specific goal, the obtained adjustment equations for the different studied properties permit the comparison between the pulps and the study of the effects of the operating conditions. In what concerns the analysis of the operating conditions, one verified that the rotor speed of rotation has a major influence on the pulp and paper properties. A characteristic for paper production is the need to combine paper properties that develop in opposite directions as refining proceeds, leading to conjugated properties optimization. A detailed analysis of tear index as a function of traction was made for the three materials, in order to characterize papermaking pulps. A selection of raw material and an energy optimization of the operating conditions to obtain different types of paper were also made. Three different types of papers were included: the multi-layered paper for bags, writing paper for notebooks and printing paper before sizing.

HEAT EXCHANGER NETWORK OPTIMIZATION USING INTEGRATED SPECIALIZED SOFTWARE FROM ASPENTECH AND GAMS TECHNOLOGY

SUAREZ, Andres Felipe* *Universidad Nacional de Colombia, Colombia*

This article presents a generalized methodology of a heat exchanger network process optimization taking as an example a Natural Gas Processing Plant WDGC (Western Desert Gas Complex) of the Egypt National Natural Gas Company (GASCO) with the use of Process Engineering specialized software from AspenTech and GAMS Technology companies. To obtain the best design on energetic use, those designs were optimized in the heat exchanger surface area, rational use of utilities and economic costs. Several modifications on the heat exchanger train of the natural gas processing plant are proposed to have opportunities on energy conservation, as an economical and environmental solution. The steady-state simulation of the plant was made with HYSYS software through the implementation of Pinch Technology; it was possible to calculate the minimum requirements of heating and cooling for the processing plant. Finally, using Aspen Energy Analyzer software from AspenTech suite and the optimization software GAMS, a series of optimal HEN's are generated, in which is possible to recover a high quantity of heat at minimum total costs. This improve on energy performance and costs savings could be made only with the installation of two heat exchangers to the existing heat exchanger network

MODELING AND OPTIMIZATION OF AUTO-THERMAL AMMONIA SYNTHESIS REACTOR USING THE GRAVITATIONAL SEARCH ALGORITHM

LOBATO, Fran Sérgio* *Federal University of Uberlândia, Brazil*
BORGES, Romes Antônio *Federal University of Goiás, Brazil*
STEFFEN JR, Valder *Federal University of Uberlândia, Brazil*

This paper presents the modeling and optimal design of an auto-thermal ammonia synthesis reactor. The main objective in the optimal design of an auto-thermal ammonia synthesis reactor is the estimation of optimal length of reactor for different top temperatures with the constraints of energy and mass balance of reaction and feed gas temperature and mass flow rate of nitrogen for ammonia production. Ammonia production depends on temperature of feed gas at the top of the reactor (top temperature), the partial pressures of the reactants and the reactor length. The optimal problem requires maximization of an objective function subject to a number of equality constraints involving solution of coupled differential equations. To solve this optimization problem, the Gravitational Search Algorithm is used. This evolutionary algorithm is based on the Newtonian gravity and the laws of motion. The preliminary results are compared with other approaches available and indicate that the proposed methodology characterizes a promising alternative for dealing with this type of problem.

AN OPTIMAL APPROACH FOR MULTICOMPONENT DISTILLATION IN A PETROCHEMICAL PLANT IN OPERATION

OSORIO, Maria A. *UNIVERSIDAD AUTONOMA DE PUEBLA, Mexico*
MUNOZ, Erika* *UNIVERSIDAD AUTONOMA DE PUEBLA, Mexico*
SANCHEZ, Abraham *UNIVERSIDAD AUTONOMA DE PUEBLA, Mexico*

This paper addresses the particular case of the multicomponent distillation of methanol in a petrochemical industry in operation in Puebla, Mexico, with a process synthesis approach that uses a superstructure containing all possible combinations in which the elements can be separated from the mixture. Real data from sequence of the current distillation columns used are combined with the data obtained with simulation using HYSYS. This superstructure contains the actual data for the option that is currently in operation and the data obtained with simulation for options that have not been implemented. We used simple distillation columns in the simulation to reduce the complexity of the design. The process synthesis is a methodology that uses a superstructure to define all the possible options that can carry out a process by means of a combinatorial optimization model that uses the minimization of fixed and variable costs of energy and flow as its objective function and mass and energy balances of all the possible combinations as constraints. The solution provides the optimum flow chart that should be carried out in the process In this model, computer simulation is a key tool for analysis, synthesis and evaluation in the process design. We built a reliable model, because we did not perform simplifications in the calculations for the simulations and, in consequence, the design optimization model presented is rigorous, and can be used to discriminate alternatives, or to prevent strain on time and money on projects that do not offer a good economic potential. The equipment sizing and the values of the operating variables determine the function cost that corresponds to the superstructure. The solution of this combinatorial optimization model provided investment, operations, service and energy costs, as well as the optimal sequence of distillation columns for the methanol synthesis. In this particular case the solution showed that the real separation currently used in the petrochemical industry in Puebla is operating with optimal option.

LDM - DIGITAL READER TO HYDROMETRIC WINDLASS

MORAES, Marcos Freitas de* *UFPr/Unioeste, Brazil*
GRAMANI, Liliana Madalena *UFPr, Brazil*

The knowledge of the process flow shower can be determined through hydrological simulation models, which are classified according to need and depth of study. One of the most widely used equipment among researchers in the hydrological modeling is the windlass hydrometric. This device serves for the determination of flow streams and works in conjunction with a pulse counter (or counter turns), which rotates in accordance with its propeller speed at the point of the depth to be measured and the counter only records how many times happened turning in a given time. The windlass hydrometric instruments are designed to rotate at different speeds according to water velocity. The relationship between water velocity and speed of rotation of the reel is the equation of the windlass. This equation is provided by the

manufacturer of windlass, but it should be checked periodically, because it can be changed by the wear of parts. Measure the velocity of the flowing river at various points both horizontally and vertically, that is, readings are taken at various depths and across the river bed. These measurements tend to a high margin of error, because the researcher notes and performs all calculations manually, providing a high probability of error in measurement. Another problem is the delay required to collect the data, and at each point are made at least two information collections. The idea of this project is to develop a equipament - called LDM - Digital Reader for Hydrometric Windlass - that is coupled to the windlass, instead of the pulse counter and automatically the information depth, position of the windlass, number of twists, turns per second, point, average speed in the vertical area of influence and flow is stored and transferred to a memory card SD / MMC, thus allowing higher data reliability and speed in the polls. Together they will develop a software for manipulating and organizing data collected by the equipment and by calculating the numerical data by the least squares method, determine the curve-key of the river in study. This equipment would have intended to support the universities in teaching, research and extension in the area of hydrology, as well as the Institutes of the Environment, because the intent is to develop a low cost equipment and easy handling.

INTERIOR POINTS AND BRANCH-AND-CUT HYBRIDS METHODS APPLIED IN TRANSPORT COST AND ENERGY GENERATION PROBLEMS OF SUGARCANE BIOMASS

DE LIMA, Camila* *Universidade Estadual Paulista - UNESP, Brazil*
BALBO, Antonio Roberto *Universidade Estadual Paulista - UNESP, Brazil*
SILVA, Helenice de Oliveira Florentino *Universidade Estadual Paulista - UNESP, Brazil*

The use of biomass as an alternative source of energy cogeneration is creating excellent prospects for energy and environmental solutions in the electricity sector. The sugarcane comes in this study because it is much cultivated in Brazil and generates a lot of waste after cutting. There is a preoccupation with the used harvest system in this culture, called semi-mechanized, because is realized the manual harvest with the burning of the leafs and straw. Although it is useful in areas of high slope where there is no machines activity, this harvest kind can cause fire and pollution to environment. The government has imposed new rules and ordinances to ban the burning in order to solve this problem. In the mechanized harvest system with raw sugarcane the interest is energy cogeneration because the problem is related to the waste remaining in the soil which favors the appearing of parasites and itself contamination. Therefore, the harvest, the recovery and the utilization of waste biomass has been the object of study. The procedures of harvesting, transportation and processing of waste biomass involve a large number of machinery, thus one of the difficulties in the use of waste is in the economic part. Some mathematical models based in Florentino (2006), Homem (2010) and Ramos (2010) are proposed. They consist in determinate which of the sugarcane varieties must be planted on the plots that satisfy the demands and constraints of the mill and the available area for planting (mechanized and semi-mechanized) in order to minimize the sugarcane transportation cost, to maximize the energy generation from waste biomass and to search for efficient solutions to the multiobjective problem, which has conflicting objectives of minimizing cost and maximizing energy balance. Aiming to investigate these models a hybrid procedure is proposed involving the predictor-corrector primal-dual interior points method and the branch-and-cut method (PDBC). This procedure was computationally implemented in C++ programming language that will be used to solve and to realize the numerical analysis of these problems including the multiobjective model. In this work, the PDBC method is applied in a problem of a mill of São Paulo state and the results will be compared with those published in Ramos (2010).

ENERGY EVALUATION IN THE PROCESS OF EVAPORATION-CRYSTALLIZATION FOR THE PRODUCTION OF CANE SUGAR

DOMINGUEZ, Gloria* *Instituto Politécnico Nacional, Mexico*
OSORIO, Anselmo *Instituto Politécnico Nacional, Mexico*
LOIS, Jorge Aurelio *Instituto Politécnico Nacional, Mexico*

The development of cane sugar is currently done through three stages, develops an energy assessment of the process of evaporation - crystallization in the production of cane sugar, for the realization of an energy balance that includes a sustainable development for the production of sugar. Three variables that propose to improve the control in the process of crystallization, the performance of the rate of growth of the crystals, the concentration of the dissolved sucrose and the energy balance of the process are evaluated. This paper evaluates the variables in the process of crystallization.

EVALUATION OF ECONOMIC IMPACTS ACHIEVED BY A CONTROL STRATEGY FOR TARGETING POLYMER QUALITY

QUIRINO, Poliana Pastorele da Silva * *Universidade Federal da Bahia, Brazil*
EMBIRUÇU, Marcelo *Universidade Federal da Bahia, Brazil*
PONTES, Karen Valverde *Universidade Federal da Bahia, Brazil*

The objective of this work is to evaluate the economic impacts obtained with a robust control strategy when automating a polymerization reactor that in industrial practice operates in manual control. Given the absence of on-line measurements for quality variables such as Melt Index (MI) in this process, the target polymer properties are obtained indirectly by controlling the reaction temperature. The aim is thus to satisfy the quality requirements of the resin, expressed by the MI, as well as to investigate the potential benefits arising from the improvement of the control strategy proposed, which is based on PID controllers, i.e., a low-cost approach largely accepted in industry. The controllers tuning was carried out by an optimization-based technique which can join, in a multiobjective function, several criteria for the closed-loop performance, such as modeling errors, constraints on overshoots and different disturbance signals, for servo and regulatory problems. The results show that the control strategy proposed is satisfactory for targeting the polymer quality and additionally allows minimizing production of off-spec material when compared to the manual control. Furthermore, the economic gains achieved are presented, indicating that an approach with low investment cost, if associated with optimal controller tuning, may offer alternatives for a more profitable and efficient process operation.

Reliability Based Design Optimization

INTRODUCTION OF A RESTFUL WEBSERVICE FRAMEWORK FOR COMPLEX ENGINEERING OPTIMIZATION

MAKIN, Thomas* *University of Bath, United Kingdom*
KIM, H. Alicia *University of Bath, United Kingdom*
PADGET, Julian A *University of Bath, United Kingdom*

A realistic engineering workflow often involves a potentially complex coupling of computational tools, data formats, programming languages and computing platforms, which can hinder integration of a given modelling and optimization procedure. Additional complication in a modern engineering workflow is the potential for geographical dispersion of resources and expertise within an organisation. It may not be possible or practical to relocate an analysis process to the same computational domain as all potential users of this process. A potential solution to these issues is to decouple the design tools from the workflow using standard web technologies. By incorporating a basic web server, the various workflow components can interact asynchronously with the design tools via Hyper Text Transfer Protocol (HTTP). Whilst HTTP is not the only choice for such communication, it is ubiquitous and probably the most widely supported web communication protocol This paper presents a web service implementation of an engineering design tool - the specific tool for the demonstrative case study being the adaptive Radial Basis Function metamodelling technique. A RESTful approach is employed whereby the model is exposed to the user as an HTTP resource accessible via a simple Uniform Resource Identifier (URI). The paper provides an overview of the portable technologies employed and includes a discussion of how web services may be easily incorporated into an existing engineering workflow. The potential advantages of using a series of web based design components are demonstrated using a multi-platform example combining a range of tools including MATLAB, C++, Python and legacy Fortran code. With this approach each significant part of the process can effectively operate behind a firewall thus enabling the components to be developed, tested and deployed independently. This produces a series of loosely coupled software tools with well defined interactions that help the user to set up manageable, robust and flexible workflows. We demonstrate how this is a potentially powerful framework for modelling and optimization even when a tool was not originally designed for use across the wider internet.

RBDO WITH NON-GAUSSIAN VARIABLES BY USING A LHS- AND SORM-BASED SLP APPROACH AND OPTIMAL POLYNOMIAL REGRESSION MODELS

STRÖMBERG, Niclas* *Jönköping University, Sweden*

A general sequential linear programming (SLP) approach for reliability based design optimization (RBDO) with non-Gaussian random variables is presented. The RBDO problems are formulated by using optimal polynomial regression models (OPRM) as surrogate models and S-optimal design of experiments (DoE). The S-optimal DoE is obtained by maximizing the average mean of the distances between the nearest neighbors. Finite element simulations are performed for the S-optimal DoE and corresponding OPRM are obtained by a genetic algorithm. In such manner not only optimal regression coefficients are generated but also optimal polynomials. The RBDO problems are solved by introducing intermediate variables defined by the iso-probabilistic transformation at the most probable point. By using these variables in the Taylor expansions, a corresponding deterministic linear programming problem is derived, which is corrected by applying

second order reliability methods (SORM) as well as Monte Carlo simulations. For low target values on the reliability crude Monte Carlo simulations are used, but for high targets a Latin hypercube sampling (LHS) approach is utilized. The implementation of the suggested sampling- and SORM-based SLP approach is efficient and robust. This is demonstrated by presenting trade-off curves between the objective function, constraints, variables and the target of reliability.

RELIABILITY ANALYSIS OF RIVER BED SIMULATION MODELS

CLEES, Tanja *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
NIKITIN, Igor *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
NIKITINA, Lialia* *Fraunhofer Institute for Algorithms and Scientific Computing, Germany*
KOPMANN, Rebekka *Federal Waterways Engineering and Research Institute, Germany*

Numerical simulations of river bottom evolution can be used for evaluating river engineering concepts and efficient operation of the natural and manmade waterways. The requirements to the precision of such simulations as well as to their ability to represent the real behaviour of the river bed morphodynamics are very high due to the large impact of civil water engineering to nature and society. In morphodynamic numerical models model parameters, initial conditions and input data can be uncertain due to the natural variability, the deficient description of the physical processes in the model and the imprecision of the model parameters. The propagation of these uncertainties can have serious implications in the reliability of the simulation results. Therefore, it is necessary to identify the various sources of uncertainty and to quantify their contributions to the variance of the model result. We present a novel approach for reliability analysis of coupled morphodynamic - hydrodynamic simulations of river bed evolution. It consist of sensitivity analysis of the simulation results to the variation of input parameters with linear FORM, preliminary estimation of non-linear effects and final determination of large confidence limits in substantially non-linear problems. For this purpose adaptive design of experiments and Monte Carlo method accelerated by RBF metamodeling of bulky simulation results have been developed. A realistic application case is used to demonstrate efficiency of the approach. Two artificial flood events have been simulated along 10 km of river Danube, while 13 model parameters have been varied applying normal and distorted initial distribution. 68%, 95% and 99.7% confidence intervals for resulting river bottom evolution have been determined and the non-linear distortions of the resulting distribution have been demonstrated.

THE SIMULTANEOUS COMPUTATION OF THE EQUILIBRIUM AND THE RELIABILITY OF RC CROSS SECTIONS USING OPTIMIZATION TECHNIQUES

SILVA, Marcelo Araujo da* *RM SOLUÇÕES ENGENHARIA LTDA., Brazil*
BRASIL, Reyolando *UNIVERSIDADE FEDERAL DO ABC, Brazil*

The main goal of this work is to present the evolution of the use of optimization techniques from the computation of the equilibrium until the optimization of RC cross section considering the reliability. First of all, the optimization is used to verify a given RC cross section computing the equilibrium of the section according to NBR-6118 (2003), in a second problem, the cost of this section is minimized and the equilibrium is accomplished simultaneously and finally the cross section is equilibrated, the cost minimized and a certain probability of failure is imposed using optimization techniques. The objective is to explore the power of the optimization to solve simultaneously problems that often are solved separately. Concepts of optimization, equilibrium, reliability and reinforced concrete are used in this work to show that these three problems can be solved in only one problem.

RELIABILITY BASED DESIGN OPTIMIZATION FOR NONLINEAR STATIC TRUSS SYSTEM CONSIDERING REDUCED-ORDER MODELING

MOTTA, Renato de Siqueira* *UFPE - CTG, Brazil*
AFONSO, Silvana Maria Bastos *UFPE - CTG, Brazil*

In most engineering applications, the traditional optimization approach is to consider deterministic models and parameters on the design of engineering system. Unfortunately, the deterministic approach generally leads to a final design whose performance may degrade significantly or constraints can be violated due to perturbations arising from uncertainties. In this scenario a better target is an optimal design that gives a low probability of failure. The probability of failure for a specific mode of failure is computed via reliability

analysis. The process to find such optimal is referred to as reliability based design optimization (RBDO). In this paper, we use RBDO to obtain designs for a prescribed probability of failure. Commonly uncertainty in material properties, variation in geometry, uncertainty in loading and boundary condition, etc. are included in the design process by introducing simplified hypothesis which does not present the probability of failure. The efficient way to consider the uncertainties and to compute the probability of failure is through reliability analysis. Here, we discuss two reliability analysis method that exploit deterministic computer models: Monte Carlo (MC) method and First Order Reliability Method (FORM). These approaches consider the computational system (code) as a black-box, which returns the reliability index and probability of failure of a specific problem given its uncertainties. As the reliability analysis could be very costly, especially when using the MC method, approximation techniques based on reduced-order modeling (ROM) approach are also incorporated in our procedure via proper orthogonal decomposition (POD) method. POD method will be employed to provide the surrogate model for fast nonlinear analysis output for trusses. Such technique approximates the numerical model by reducing the total number of degree of free-dom of the original problem (high fidelity (HF) model). The POD is a ROM that, basically, projects the problem into a subspace formed by a optimum orthonormal basis functions, in the sense that it consider the most significant shape (greatest variance) of the output subspace. A Structural sizing optimization (SSO) algorithm incorporating such procedure in the structural, sensitivity and reliability analyses will be used to obtain efficient optimal trusses design for a prescribed target reliability index. A case study will be presented to illustrated the developed procedure.

Shape and Size Optimization

OPTIMIZATION OF THE MAGNET SYSTEM FOR THE LORENTZ FORCE VELOCIMETRY OF LOW CONDUCTING MATERIALS

ALFERENOK, Artem* *Ilmenau University of Technology, Germany*
LUEDTKE, Ulrich *Ilmenau University of Technology, Germany*

The Lorentz Force Velocimetry (LFV) is a contactless method to measure the flow rate of electrically conducting fluids [1]. The LFV working principle is based on the interaction of the fluid flow with the transversal constant magnetic field. The fluid flows in the channel across the magnetic field which is generated by the magnet system locating near the channel and being at rest. Because of the relative motion between the flow and the magnet system the eddy current arises in the flow. Interacting with the primary magnetic field, the eddy current causes the Lorentz force which brakes the flow. According to Newton's third law, the same force acts on the magnet system in opposite direction. The Lorentz force is proportional to the velocity and electrical conductivity of the fluid as well as squared magnetic flux density [1]. Knowing these parameters it is possible to measure the flow rate by measuring the Lorentz force. The LFV is a well-developed technique to measure the flow rate of liquid metals [2]. We aim to develop LFV for low conducting materials. The main problem is that the expected Lorentz force is roughly a million times smaller for low conducting materials than for liquid metals. The only way to increase the Lorentz force is to optimize the magnet system. Since the weight of the system is also restricted, we used the permanent magnets arrays to generate the magnetic field [3]. To optimize the geometric dimensions of the magnet system, different optimization techniques, such as polynomial approximation and genetic algorithms, have been used. To analyze the problem a 3D finite element model was developed using commercial software COMSOL. Optimization was performed using optimization toolbox in MATLAB. References [1] A. Thess, E. Votyakov, and Y. Kolesnikov, Lorentz Force Velocimetry, Phys. Rev. Lett. Vol. 96, 164501, 2006. [2] A. Thess, Y. Kolesnikov, Ch. Karcher, E. Votyakov, Lorentz Force Velocimetry - A contactless technique for flow measurement in high-temperature melts, Proceedings of 5th International Symposium on Electromagnetic Processing of Materials, pp. 731-734, 2006. [3] M. Werner, B. Halbedel, Anwendung von Halbacharrays in der Lorentzkraftanemometrie, Workshop Elektroprozesstechnik, 2011.

MINIMIZATION OF VIV USING AN ALE-FE FORMULATION AND FRACTIONAL STEP METHOD IN FLUID STRUCTURE INTERACTION PROBLEMS

FARIAS FILHO, Ulisses P.* *UFPE, Brazil*
ANTUNES, Alessandro R. E. *UFPE, Brazil*
BASTOS, Silvana M. A. *UFPE, Brazil*
LYRA, Paulo R. M. *UFPE, Brazil*

The analysis of fluid-structure interaction problems involves the modification of the computational domain as the geometry under consideration is moving with time. In several engineering applications, to avoid updating the computational mesh too frequently, an arbitrary Lagrangian Eulerian (ALE) formulation is adopted together with a mesh movement algorithm. In this paper, a stabilized finite element method, based on a Fractional step Method is extended to deal with bidimensional incompressible flow problems with moving boundaries using an ALE formulation. The algorithm adopted to build the dynamic mesh is based on the Modified Laplacian Equation and will be fully described. The structural model considers a simple rigid body with two uncoupled degrees-of-freedom. Some important numerical and implementation issues are also addressed. Finally, the whole system is used to study external flows over a circular cylinder, including the analysis of a fixed cylinder, a moving cylinder with a prescribed forced cross-flow oscillation and a moving cylinder due to the interaction between the fluid and a rigid body. The vortex induced vibrations phenomena is evaluated, which is of great importance for the analysis of the engineering projects, and the reduction of the vibrations is analyzed by application of acoustic excitation over the cylinder. In the aim to find the acoustic excitation parameters that lead to the minimization of vibrations of the cylinder, an optimization problem is formulated. Due to the high computational cost associated with the numerical simulations, surrogate models are built using Kriging based data fitting scheme.Therefore, the optimization tools will be used in which the optimization algorithm will operate solely on the surrogates to be constructed, based on few high fidelity model evaluations (computational costly) obtained for a limited number of designs generated by a design of experiments technique (DOE). The optimum solutions will be obtained using the Sequential Approximation Optimization strategy (SAO). A trust region based method is used to update the design variable space for each local optimization solution (SAO iteration). The local optimization algorithm of choice is the sequential quadratic programming (SQP).The results found are presented and discussed.

A COMPREHENSIVE COMPARISON OF SHAPE DEFORMATION METHODS IN EVOLUTIONARY DESIGN OPTIMIZATION

SIEGER, Daniel* *Bielefeld University, Germany*
MENZEL, Stefan *Honda Research Institute Europe, Germany*
BOTSCH, Mario *Bielefeld University, Germany*

Design optimization targets the performance improvement of certain physical aspects of real world objects, e.g., in the automotive or aeronautical domain. The success of an optimization is strongly coupled to the efficient interplay of three major ingredients: optimization algorithm, shape representation, and design evaluation method. Recently, shape deformation methods originating from computer graphics and geometric modeling have been successfully integrated in a design optimization framework using evolutionary algorithms as stochastic global optimization algorithm. In particular, the combination of free-form deformation (FFD) and evolutionary optimization has been proven to be a powerful tool for improving complex aerodynamic shapes. Within such an optimization framework the deformation module allows to manipulate a given shape by adjusting a set of control points constituting the design parameters determined by the selected evolutionary algorithm. Despite their successful application, an up-to-date survey of deformation techniques for shape optimization problems is currently lacking from the literature. In this paper, several state-of-the-art shape deformation methods are introduced and investigated for their use in design optimization problems. Starting from classical FFD and its direct manipulation variant we broaden our investigation to more flexible methods such as cage-based deformations as well as deformations based on radial basis functions. Especially the latter method is significantly different since it does not require any control volume. We evaluate the methods regarding several criteria such as computational performance, numerical robustness, flexibility, and quality. Finally, the different methods are applied in an evolutionary optimization framework to improve the drag of a simplified Honda Civic model. Based on this framework we analyze and compare the strengths and weaknesses of the different deformation methods in a practical optimization scenario utilizing computational fluid dynamics simulations for aerodynamic performance calculation.

INTERIOR POINT METHODS FOR SHAPE OPTIMIZATION IN ELECTROMAGNETIC CASTING

CANELAS, Alfredo *Instituto de Structuras y Transporte, Facultad de Ingeniería, Universidad de la Republica, Uruguay.*
HERSKOVITS, José *Mechanical Engineering Program - COPPE - Federal University of Rio de Janeiro, Brazil*
ROCHE, Jean* *Institut Elie Cartan de Nancy, Université de Lorraine, Nancy, France*

Interior Point Methods and Simultaneous Analysis and Design optimization methods are fundamental numerical techniques for shape optimization of large problems. In this paper we consider the application of this methods to the direct and inverse Electromagnetic Casting problem. Electromagnetic Casting is based on the repulsive forces that an alternating electromagnetic field produces on the surface of liquid metals. The electromagnetic field is induced by an externally imposed alternating current. In the direct problem the position and shape of the inductors are given and the magnetic field created by them produces a surface

pressure on the vertical column of liquid metal that change its shape until an energetic variational formulation for the equilibrium relation on the boundary between the electromagnetic pressures and surface tensions is satisfied. The inverse problem consists of locating the inductors in order to have a horizontal cross-section of the molten metal as close as possible to a prescribed shape. In this work we consider a realistic case where each inductor is a set of bundled insulated strands and the electric current density is assumed uniform on the entire cross-section of the inductor. In order to design suitable inductors two different approaches are proposed, the first one looks for a set of inductors such that the distance between the computed shape and the given target one is minimized. In the second approach the error of the equilibrium equation for the target shape is minimized, this fact allows a minor computational effort. To develop a numerical method we consider a Simultaneous Analysis and Design optimization technique, SAND, which is a formulation that includes the state variables as unknowns of the mathematical program and the state equations as equality constraints. The finite dimensional optimization problem obtained was solved employing the Feasible Arc Interior Point Algorithm, FAIPA. Adaptive techniques are considered in order to accelerate the convergence of the numerical algorithm. Numerical computations for several examples of the direct and inverse problems are presented to show the efficacy of the proposed formulations in the design of suitable inductors. The authors would like to thank the Brazilian Research Councils CAPES, CNPq and Faperj, the French Councils COFECUB, INRIA and CNRS and the Uruguayan ANII for financial support.

SHAPE OPTIMIZATION FOR A SEEPAGE PROBLEM USING SMALL AMPLITUDE HOMOGENIZATION

GUTIÉRREZ, Sergio *Pontificia Universidad Católica de Chile, Chile*
MURA, Joaquín* *Pontificia Universidad Católica de Valparaíso, Chile*

In this work we propose a method to minimize the steady flow through a dam made of two materials having different porosities. The idea is to find the optimal position of the less porous material, whose volume is given. This is performed by considering the Stokes system. The optimization method follows from previous works based on Small Amplitude Homogenization, where it is assumed that the contrast between the values of the porosity is not very large. For this purpose, we construct an asymptotic approximation up to second order with respect to the contrast parameter, which give us a new set of simplified equations for the evaluation of a steepest descent method. We remark that, in particular, this evaluation involves the computation of the H-measure associated to the Stokes problem. Special attention is made to determine the free boundary condition for the seepage gravity dam problem. We perform fixed point iterations for determining the seepage surface during the optimization process. Finally, some numerical results will be shown to demonstrate the performance and reliability of the proposed method.

Solid Mechanics and Materials

A FINITE ELEMENT APPROACH USING AN AUGMENTED LAGRANGIAN METHOD TO SIMULATE IMPACT PROBLEMS UNDER LARGE 3D ELASTOPLASTIC DEFORMATION

BANDEIRA, Alex Alves * *Department of Construction and Structures, University of Bahia, Brazil.*, *Brazil*
PIMENTA, Paulo de Mattos *Department of Structures Engineering, University of São Paulo, Brazil.*, *Brazil*

In this work the Augmented Lagrangian Method is used to solve impact problems with friction in solid mechanics. The purpose of this paper is to present the Augmented Lagrangian algorithmic to simulate numerical examples of impact problems using the formulations of contact mechanics, non-linear dynamic and the elastoplasticity algorithm based on an associated von Mises yield function formulated in principal axes, considering the possible sliding of slave node from one surface to the adjacent one. The formulation is derived based on exact linearization. The bodies in contact undergo finite deformation within an elastoplastic range. For the contact formulation within the finite element method, the matrix formulation for a node-to-surface element consisting of a master surface with four nodes and a contacting node is derived. Here, the discretised contact surfaces are not smooth, i.e. there is no continuity of the normal vector between the adjacent surfaces. At the edge between the surfaces the normal is not uniquely defined, that needs a special algorithmic treatment. Several numerical examples for impact problems in elastoplastic range are presented to show the ability of these algorithmic. These examples are modeled by using brick elements.

EFFECTIVE NUMERICAL SOLUTION OF ILL-CONDITIONED BOUNDARY-VALUE PROBLEMS IN MECHANICS OF SOLIDS

BRIGADNOV, Igor Albertovich* *St. Petersburg State Mining University*, *Russian Federation*

It is well-known that some practically important boundary-value problems in Mechanics of Solids are ill-conditioned, for example, in perfect plasticity, limit analysis and finite elasticity. At present for numerical solution of these problems the finite element approximation (FEA) is widely used. But standard methods such as the Newtonian procedure and the Richardson procedure of simple iterations are very sensitive to condition number of appropriate resolving systems of algebraic equations. The main cause of this phenomenon consists of the following: the global stiffness matrix can have rows with essentially different factors. As a result, this finite dimensional problem needs special preconditioned numerical methods. The original decomposition method of adaptive block relaxation (ABR) is proposed for numerical solution of ill-conditioned finite dimensional problems. The ABR method takes into account essentially nonlinear deformation of material and practically disregards the condition number of the global stiffness matrix. Its main idea consists of iterative improvement of zones with "proportional" deformation by special decomposition of domain (variables) and separate calculation in these zones (on these variables) on every iteration step. Zones of essential nonlinear deformations, as usual don't known a priori, therefore, they are corrected adaptively on every iteration step. The global convergence theorem for the ABR method is proved. Numerical results show that to find the deformed configuration, this method has qualitative advantages over standard techniques.

MODELLING OF FATIGUE CRACK PROPAGATION USING PIECEWISE DETERMINISTIC MARKOV PROCESSES

BEN ABDESSALEM, Anis* *Université de Bordeaux, France*
TOUZET, Marie *Université de Bordeaux, France*
GÉGOUT-PETIT, Anne *Université de Bordeaux, France*
PUIGGALI, Monique *Université de Bordeaux, France*
AZAIS, Romain *Université de Bordeaux, France*
ELEGBEDE, Charles *EADS Astrium, France*

Fatigue crack propagation is stochastic phenomenon in nature due to the inherent uncertainties that can affect material properties and environement conditions. Stochastic modelling offers an appropriate framework for predicting crack propagation since it is intended to include sources variabilities. In this work, we propose to model crack propagation dynamics as Piecewise Deterministic Markov Processes (PDMP) using random crack growth models. Paris's law commonly used in litterature cannot adequately describe the behaviour of crack propagation before failure. To overcome this drawback, a new modelling that consists to combine Paris and Forman laws is proposed. Empirical curves of Virkler et al. [1] was used to adjust the parameters of PDMP. A cluster of cracks obtained by numerical simulations is found with an excellent agreement compared to experimental data. In addition, the proposed modelling allows us to estimate accurately the crack propagation rate and the transition time from Paris to Forman regime. The effect of toughness on crack propagation is also investigated.

ON THE USE OF NEURAL NETWORK APPROXIMATOR WITH JACKKNIFE RESAMPLING APPROACH FOR MODELING A LOCAL POROSITY MEAN AND VARIANCE IN THE CASE OF THE SINTERED STAINLESS STEEL POWDER AISI 434L DOPED WITH MN

PIETRASZEK, Jacek* *Cracow University of Technology, Poland*
GADEK-MOSZCZAK, Aneta *Cracow University of Technology, Poland*

Modelling the mechanical properties of sintered materials is a difficult issue. Building a reliable model of these materials require introduction of many parameters describing the physical characteristics of the material, that is very complex at the microscale. One of these important features is porosity, determined in many ways including 2D image analysis methods based on cross sections or 3D image analysis based on microtomography. Such an analysis requires determining the area of interest where imaging characteristics will be subjected to averaging. Larger size of the area of interest leads to characteristics of a small locality. Smaller size, approaching the size of the grains, in turn, results in very irregular course of the predicted porosity. Apart from this, image analysis is also highly time-consuming process. It would be useful to develop a method that allows fast and convenient determination of sufficiently smooth model of the porosity in the area concerned. For this purpose, the authors propose to use a set of values of porosity (p), measured by 2D image analysis methods at disjoint, sufficiently small regions (with coordinates of (x, y)) that will serve as a collection of triple data to determine the continuous response surface of porosity along with the variance. For such a set ((x, y), p) of size n, the jackknife delete-1 resampling approach is used, which gives n resampled subsets ((x, y), p) of size (n-1) by sequentially removing one data point. Each such subset is used, separately, to identify a neural network approximator, which in turn determine a response surface of predicted porosity. Then, the mean and variance of porosity is estimated at the desired points, basing on the obtained set of n resampled approximators and jackknife delete-1 approach. The proposed approach was applied to determination of the local porosity in the sintered ferritic-austenitic stainless steel powder AISI 434L with additions of Mn and Ni. Microstructures images were analyzed using ADCIS Aphelion software. Neural networks were modeled using StatSoft Statistica package. The jackknife approach calculations of mean values and variances were processed in PTC Mathcad numerical software.

MATRIX COMPRESSION STRATEGIES AND THEIR PROPERTIES FOR WAVELET BEM OPTIMIZATION

BARGI, Khosrow * *University of Tehran, Iran*
HOOSHMAND, Massoud *University of Tehran, Iran*

One of the major interests in boundary element method (BEM) is the development of the numerical technics which enhance the performance of the BEM in large-scale problems. The use of the wavelets as basis function

is accepted as a fast solution comparable to the fast multiple BEM. Many coefficients of the equations , which are defined as the integrals including the fundamental solutions and the basis on boundary, have small values owing to the vanishing moment property of wavelets. In the present paper , we investigate the number of non-zero matrix entries generated by the wavelet BEM using Beylkin-type and Schneider's compression algorithms.These methods are used together with the non-orthogonal wavelets that have been proposed by authors.The compression is performed so that the amount of storage (and computational work) is minimized without reducing the accuracy of boundary equation solution.To avoid the unnecessary integration concerning the truncated entries of coefficients matrix, a priori estimation of the matrix entries is introduced.The matrix compression for the proposed wavelet BEM enables us to generate a sparse matrix. The matrix truncation scheme applied using the Schneider level-dependent and the Beylkin-type compression methods and the results are compared. The matrix compression rate using the Beylkin-type is greater than or similar to that using Schneider's level-dependent scheme.

2'D NON-ORTHOGONAL SPLINE WAVELETS AND SCHNEIDER'S LEVELDEPENDENT SCHEME FOR 3'D BEM

HOOSHMAND, Massoud* *University of Tehran, Iran*
BARGI, Khosrow *University of Tehran, Iran*
DEZVAREH, Reza *University of Tehran, Iran*

2'D Non-orthogonal spline wavelets are used as basis function in boundary elements method(BEM).This kind of wavelet has compact supports and closed-formed expression that have been proposed by authors. Besides one can choose the vanishing moments of the wavelets Independently of the order of B-splines. The adaptive meshing for boundary elements makes it possible to reduce the degree of freedom (DOF) required for a specified accuracy. Sparse coefficient matrices are obtained by truncating the small elements a priori. The level-dependent schemes enable us to reduce the matrix entries. In the present paper we investigate the matrix truncation using Schneider's level-dependent algorithm. The level-dependent truncation schemes select the truncated entries by comparing the predetermined threshold with the distance between the supports of two basis function. Through numerical examples, the efficiency of compression scheme together with Non-orthogonal surface wavelet is investigated.

DAMAGE DETECTION USING LEAST-SQUARES SINGULAR VALUE DECOMPOSITION METHODS AND TECHNIQUES TO SELECT THE BEST EXPERIMENTAL DATA

DUARTE, Horacio Valadares Duarte* *Universidade Federal de Minas Gerais, Brazil*
DONADON, Lázaro Valentim *Universidade Federal de Minas Gerais, Brazil*
FERREIRA, Ricardo Poley Martins *Universidade Federal de Minas Gerais, Brazil*

A singular value decomposition algorithm, SVD, is applied to frequency response function matrix to monitor a composite beam. The aim of the procedure is to identify a damage in a experimental healthy and damaged data set. This is made finding the minimal distance between of a measurement subset and the subspace of the healthy structure. To avoid the sensitivity of the SVD to outliers in measurement there was employed the robust value decomposition algorithm , RSVD, that uses robust statistic techniques. All subset of experimental data distances to a healthy subspace must be evaluated. Even for small dataset this procedure can lead to a huge data combinations. In this work a optimization genetic algorithm was employed to find the best combination. Some remarks are made on subset size and the ability of the procedure to assess the measurement quality.

Structural Optimization

ISOGEOMETRIC SHAPE DESIGN SENSITIVITY ANALYSIS OF MINDLIN PLATES USING MULTI-RESOLUTION APPROACH

LEE, Seung-Wook* *Seoul National University, Korea*
KOO, Bong-Yong *Seoul National University, Korea*
LEE, Taeho *Seoul National University, Korea*
CHO, Seonho *Seoul National University, Korea*

In this paper, for Mindlin plate structures, an isogeometric shape design sensitivity analysis (DSA) method is proposed using a multi-resolution technique combined with h-refinement strategy. In an isogeometric framework, the NURBS basis functions that represent the geometry in CAD systems can be directly used in both response and sensitivity analyses. The NURBS basis functions enable to incorporate exact geometry into the framework of response analysis by discretizing the domain of analysis at the early stage of geometry definition. When knot vectors are given, the NURBS basis functions are easily obtained recursively and very simple to increase the order of basis functions. The refinements are implemented to maintain the exact geometry without subsequent communication with the CAD systems. In the analysis aspects, the isogeometric analysis turns out to be more accurate than the conventional finite element method (FEM) by comparing with exact solution and shows faster convergence to the exact solution. To obtain efficient and precise adjoint shape sensitivity, correct normal and curvature information should be taken into account in shape sensitivity expressions. However, in conventional FEM using linear interpolation functions, the normal and curvature information is generally inaccurate or missing due to the lack of inter-element continuity in design space. In this paper, a continuum-based shape DSA method is developed using the multi-resolution approach. The sensitivity results are compared with analytical solutions and finite difference sensitivity to demonstrate the feasibility and accuracy of the proposed method. The analytical displacement sensitivity is compared with finite difference sensitivity, which shows excellent agreements at all the degrees of freedom.
References [1] S. Cho and S.H. Ha. Isogeometric shape design optimization: exact geometry and enhanced sensitivity. Structural and Multidisciplinary Optimization, 38(1): 53-70, 2009. [2] T.J.R. Hughes, J.A. Cottrell, and Y., Bazilevs. Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement, Computer Methods in Applied Mechanics and Engineering, 2005, 194: 4135-4195. [3] K. K. Choi and N. H. Kim, Structural Sensitivity Analysis and Optimization:Volume1, Linear system & Volume 2, Nonlinear systems and applications, Springer, New York.

ISOGEOMETRIC SHAPE DESIGN SENSITIVITY ANALYSIS OF ELASTICITY IN GCC SYSTEMS

YOON, Minho* *Seoul National University, Korea*
BAE, Sangjoon *Seoul National University, Korea*
HA, Youn Doh *Kunsan National University, Korea*
CHO, Seonho *Seoul National University, Korea*

For decades shape design sensitivity analysis using the finite element method has been studied and employed in the shape design optimization, and yet the difficulties on design parameterization and the requirement of design remodelling during optimization have remained unsolved. In the isogeometric approach, however, geometric properties are embedded into non-uniform rational B-spline (NURBS) basis and control points

and directly used in both response and sensitivity analyses. Thus, exact geometry can be represented without losing higher order geometric information such as normal vector, tangent vector and curvature. In the perspective of shape design sensitivity analysis, the accurate sensitivity of complex geometry including the effects of higher order geometry can be obtained by the isogeometric approach. Additionally, in shape design optimization, the vast simplification of design parameterization is accomplished by utilizing direct and continuous variation of CAD geometry. The analysis method using parametric space, in general, gives reliable solution when the element mesh is parallelogram and regular. However, the response behavior obtained from distorted mesh exhibits a little poor performance. This phenomenon comes from the mapping relation between the parametric and the physical spaces, which implies a loss of accuracy in approximating the response field in terms of parametric values. To overcome the difficulty, the introduction of generalized curvilinear coordinates (GCC) can be a remedy. When the physical domain is represented in terms of convective coordinates, unlike rectangular Cartesian coordinates, each basis vector at a point is defined differently in GCC. In this study, the isogeometric shape design sensitivity analysis of elasticity in GCC systems is discussed. Representing the higher order geometric information, likely normal, tangent and curvature, yields the isogeometric approach to be the best way for generating exact GCC systems from complex CAD geometry. The performance of developed isogeometric shape design sensitivity analysis is demonstrated through numerical examples. References [1] S. Cho and S.H. Ha. Isogeometric shape design optimization: exact geometry and enhanced sensitivity. Structural and Multidisciplinary Optimization, 38(1): 53-70, 2009.

SCALABLE FINITE AND BOUNDARY ELEMENT SOLUTION OF CONTACT SHAPE OPTIMIZATION PROBLEMS WITH COULOMB FRICTION

VONDRAK, Vit* *VSB-Technical University of Ostrava, Czech Republic*
BEREMLIJSKI, Petr *VSB-Technical University of Ostrava, Czech Republic*
KOZUBEK, Tomas *VSB-Technical University of Ostrava, Czech Republic*
MARKOPOULOS, Alexandros *VSB-Technical University of Ostrava, Czech Republic*
SADOWSKA, Marie *VSB-Technical University of Ostrava, Czech Republic*
DOSTAL, Zdenek *VSB-Technical University of Ostrava, Czech Republic*

For the solution of the state contact problem in contact shape optimization we propose two efficient algorithms. The first one we called Total Finite Element Tearing and Interconnecting (TFETI) domain decomposition method, which is based on finite element approximation of the state problem. The second one is based on the boundary element approximation and we call it Total Boundary Element Tearing and Interconnecting (TBETI). Their key ingredient is decomposition of the spatial domain into non-overlapping subdomains that are "glued" by Lagrange multipliers, so that, after eliminating the primal variables, the original problem is reduced to a small, relatively well conditioned, typically equality constrained quadratic programming problem that is solved iteratively. In the frictionless case we propose so-called semi-analytical method of sensitivity analysis. An especially attractive feature of this approach is the fact that relatively expensive assemble and factorization of the stiffness matrices of the subdomains is carried out only once for each update of the design variables. In the case of contact problems with Coulomb friction we apply the so-called implicit programming approach. Its main idea consists in minimization of a nonsmooth composite function generated by the objective and the (single-valued) control-state mapping. The implicit programming approach combined with the differential calculus of Clarke was used for a discretized problem of shape optimization of 2D elastic body in unilateral contact. There is no possibility to extend the same approach to the 3D case. The main problem is the nonpolyhedral character of the second-order cone, arising in the 3D model. To get subgradient information needed in the used numerical method we use the differential calculus of Mordukhovich. In our contribution we shall demonstrate efficiency of described algorithm on model and real world optimization problems. We shall compare finite element and boundary element discretization techniques and influence of Coulomb friction on resulting optimized design.

MULTI-STEP FREE-FORM OPTIMIZATION OF SHELL STRUCTURES

YANG, LIU* *Toyota Technological Institute, Japan*
MASATOSHI, SHIMODA *Toyota Technological Institute, Japan*

Shell structures, profiting from the geometries which allow for transmitting applied forces by membrane action instead of bending, have high level of load-carrying efficiency, strength-to-weight ratio and space containment capacity. They are widely used in all phases of structures in civil, mechanical, architectural,

aeronautical, and marine engineering. In designing shell structures, the shape design is essential to the required static and dynamic characteristics of the structures, and it is strongly required to find the optimal shape so as to satisfy various mechanical characteristics, functions and artistic impression if required, and make the structure light by using the minimum amount of material as well. Shape optimization methods for shell structures can be classified into a parametric method and a parameter-free one. Most of the optimization methods proposed in previous studies are parametric methods, which need shape parameterization in advance, and the obtained shape is strongly influenced by the parameterization. This paper presents a new shape optimization methodology for designing optimal shapes of shell structures with two-step free-form optimization, which is a parameter-free method without any shape parameterization. In the first step, a shape is varied in the normal direction to the surface in order to determine the optimal curvature distribution. In the second step, the optimal boundary shape is determined while maintaining the optimal curvature distribution of the surface determined in the first step. As an application of this methodology, the mean compliance minimization problem of shell structures is dealt with in this paper. The problem is formulated as a distributed-parameter shape optimization problem, and a shape sensitivity, called a shape gradient function, is theoretically derived for both steps using the Lagrange multiplier method and the formula of the material derivative. The each shape gradient function on a design surface or boundaries is used as a distributed external force in each step to determine the optimal shape, which is the H1 gradient method modified by the author for shell design problem from the original one. With this approach, the jagged shape problem caused by parameter-free method is resolved, and a smooth optimal shell with free-form surface and boundaries can be obtained. Several calculated examples are presented to demonstrate the effectiveness and practical utility of the proposed methodology.

STRUCTURAL SHAPE OPTIMIZATION USING SHOR'S R-ALGORITHM

WILKE, Daniel N.* *University of Pretoria, South Africa*

This study investigates the suitability of the r-algorithm developed by the late Prof. Shor to optimize structural shape optimization problems. The r-algorithm is a subgradient method of the larger class of non-smooth optimization algorithms. Although, the objective and constraint functions in structural shape optimization are often treated as smooth for optimization purposes, the actual numerically computed functions are often non-smooth or even discontinuous. This is usually a consequence of the numerical strategy employed to solve the solid mechanics boundary value problem for various candidate boundaries of the spatial domain. The solid mechanics boundary value problem is generally solved numerically in it's weak form using the finite element method (FEM). FEM requires a discretization of the spatial domain also known as a mesh. This is necessary to compute a system of pure algebraic equations from the system of mixed partial differential and algebraic equations of the solid mechanics boundary value problem. As shape optimization aims to find the optimal spatial boundary it follows that the spatial domain changes as the optimization progresses. The numerically computed objective and constraint functions are usually smooth when the mapping of the mesh between the spatial domains is continuous and smooth. However, it is often required that the spatial domain is re-meshed to ensure that the system of algebraic equations is non-singular. In this study we consider a set of well-known shape optimization test problems. We numerically compute the set of test problems to be smooth i.e. employing a mesh movement strategy between spatial boundary changes. Also, we compute the set of test problems to be slightly and severely discontinuous by imposing remeshing between spatial boundary changes. Although we apply the r-algorithm to discontinuous optimization problems as opposed to non-smooth optimization problems, preliminary results are promising and shows a practical benefit of using the r-algorithm on the type of discontinuous optimization problems arising in this study. The suitability of the r-algorithm on the computed test problems are evaluated and compared to a newly proposed gradient-only variant of the r-algorithm. The gradient-only r-algorithm was specifically developed to deal with the type of discontinuous optimization problems present in this study.

ASSESSMENT OF PHYSICAL SURROGATE PERFORMANCE IN THE SEQUENTIAL APPROXIMATE OPTIMIZATION OF SPACE TRUSSES

BASTOS AFONSO, Silvana Maria* *UFPE, Brazil*
HOROWITZ, Bernardo *UFPE, Brazil*
DA SILVA, Marcelo Ferreira *UFPE, Brazil*

Surrogate models are increasingly being used in simulation based optimization procedures to overcome high computational cost and to ameliorate the numerical noises that commonly arise in such problems. Typically Surrogate modeling techniques are grouped into functional and physical (hierarchical fidelity) categories. The first technique encompasses different approaches such as data fit schemes, Taylor series (TS), and reduced basis methods. Physical surrogates, exploit physically based varying fidelity models (e.g., coarse-mesh simulations, analytical formulas, simplified physics in a FE model). Due to the fact that the low-fidelity model encodes certain knowledge about the original structure, physical surrogates typically exhibit better generalization properties than the functional ones. Such models can be used alone or as alternative, a surrogate model (multi-level approach) can be built by enhancing the physical model by appropriate corrections terms derived from a limited amount of the high-fidelity model data. Although problem dependent, physically based varying fidelity models are attractive tools to be investigated, and in this work a physical model is proposed for the practical problem of the design optimization of space trusses. We will focus on the development of varying fidelity physical based approaches for minimum compliance design of space truss systems. For this particular purpose a classical model used in the past mainly for behavior prediction and still extensively used today by practical engineers in an initial design stage, is investigated for use. In this context, a grid analogy is used in substitution to the real truss and correction models are used to approximate the difference between the real (truss) and approximate (grid) FE model. Additive and multiplicative are the corrections forms to be investigated. The correction terms can be constructed using data fitting schemes or Taylor series expansion. In this process different levels of consistency between the surrogate and the high fidelity model are imposed. In order to check the performance of the proposed physical varying fidelity models, TS and kriging approximation strategies are implemented. Two model assessment strategies are implemented to check if a particular created model is adequate. An example of a 3D truss will be studied and comparisons between the different approaches will be conducted.

SOLVING CONSTRAINED STRUCTURAL OPTIMIZATION PROBLEMS USING A PSO AND AN ADAPTATIVE PENALTY TECHNIQUE

SILVA, Allan Fonseca* *PEC/COPPE/UFRJ, Brazil*
LEMONGE, Afonso Celso de Castro *MAC/UFJF, Brazil*
LIMA, Beatriz Souza Leite Pires de *PEC/COPPE/UFRJ, Brazil*
JACOB, Breno Pinheiro *PEC/COPPE/UFRJ, Brazil*
BARBOSA, Helio José Correa *LNCC, Brazil*

The use of evolutionary algorithms has been expanding over the years, especially the use of the technique known as PSO (Particle SwarmOptimization) to solve optimization problems. The PSO, in addition to being easy of computational implementation, can be considered a robust, efficient and competitive algorithm compared with other nature inspired algorithms and still does not require objective functions that are derivable. In this work, we analyzed some engineering optimization problems with constraints such as minimizing the weights of truss where a PSO treats then as a problem without constraints by introducing an adaptive penalty scheme - APM (Adaptive Penalty Method). The APM was originally developed for use in optimization problems with constraints using genetic algorithms as a search engine and has proven to be robust and efficient. Recently this technique was used within a PSO to deal with optimization problems of mathematical functions with constraints. The APM can handle equality and inequality constraints, does not require explicit knowledge of the constraints as functions of the problema variables, it is free of parameters to be defined by the user and, it is easy to computational implementation.

OPTIMAL DESIGN OF ANNULAR AND CIRCULAR PLATES

LELLEP, Jaan *University of Tartu, Institute of Mathematics, Estonia*
POLIKARPUS, Julia* *University of Tartu, Institute of Mathematics, Estonia*

Axisymmetric plates are widely used in the mechanical engineering and in various fields of technology. In this paper the behavior of plates subjected to axisymmetrical loading is studied making use of the elastic and elastic plastic models of the material. An optimization procedure is developed for sandwich plates. It is assumed that the thickness of the carrying layers is piecewise constant whereas the thickness of the core material is constant. The problem is considered as a particular problem of the theory of optimal control. Necessary optimality conditions are derived making use of variational methods of the theory of control. The optimization problem consists in the minimization of the cost of the structure taking into account the governing equations of the problem. Governing equations include equations of equilibrium, geometrical relations and physical equations. These are different in the elastic and elastic plastic stage of loading, respectively. In the elastic stage the material behavior is described by Hooke's law for the whole plate. It is assumed that the plate operates in the elastic plastic loading stage. Therefore, one has to distinguish elastic and elastic plastic zones of the plate, respectively. In the elastic zone located near the edge Hooke's law holds good. However in the elastic plastic zone located at the central part of the plate the material of the plate obeys the Tresca yield condition and associated flow law. It appears that the plastic flow occurs according to the flow regime associated with the maximal value of the circumferential moment (the horizontal side of the Tresca yield hexagon). The set of governing equations is presented as a system of the first order differential equations in both regions. The solution of the direct problem of determination of the stress-strain state of the plate is presented, provided the plate operates in the elastic plastic range. Numerical results of optimization are compared with corresponding solutions for elastic and pure plastic problems.

STRUCTURAL OPTIMIZATION UNDER THERMAL CONSTRAINTS VIA A LEVEL-SET METHOD

MICHAILIDIS, Georgios* *Renault, France*
ALLAIRE, Grégoire *Ecole Polytechnique, France*
JOUVE, Francois *University Paris Diderot, France*

Shape and topology optimization via a level-set method [1, 6] has started attracting the interest of an increasing number of researchers and industrial designers over the last years. Beyond its flexibility to perform changes in the topology of the shape, its independence on the objective function to be minimized expands significantly its range of applicability. Industrial applications usually introduce thermal constraints, which the optimized structure has to preserve. Such constraints are related either with the performance of the structure, i.e. fast cooling of a heat radiator, or even with the manufacturing process, such as cast parts. In the last case, the cast part is required both to solidify into a predefined time interval, but also not to have very thick parts, such that the default due to contraction during solidification can be concentrated in a riser of acceptable size [3]. In this work, we imposed an upper limit on the temperature of the structure after some specific time.We solve some model of the heat equation, depending on the nature of the problem, in the domain occupied by the structure and we check if the temperature limit is violated. Then, we add a penalty functional in the initial objective function, that is a weighted sum of the compliance and the volume. We compute a shape derivative [4] of the new objective function and follow a penalization method to impose the constraint [2]. We show examples in 2-d and 3-d. References [1] Allaire G., Jouve F., Toader A.-M., Structural optimization using a sensitivity analysis and a level-set method, Journal of Computational Physics, 194, 363-393 (2004). [2] Amstutz S., A penalty method for topology optimization subject to a pointwise state constraint, ESAIM: COCV (2009). [3] Deng X.L., Proslier L., Optimization of structures under technological casting constraints, Structural Optimization 10, Springer-Verlag, 180-190, (1995). [4] Murat F., Simon S., Etudes de probl`emes d'optimal design. Lecture Notes in Computer Science 41, 54-62, Springer Verlag, Berlin (1976). [5] Tavakoli R., Davami P., Optimal riser design in sand casting process by topology optimization with SIMP method I: Poisson approximation of nonlinear heat transfer equation, Struct Multidisc Optim, 36, 193-202 (2008). [6] Wang M.Y., Wang X., Guo D., A level-set method for structural topology optimization, Comput. Methods Appl. Mech. Engrg., 192, 227-246 (2003).

STRESS ENERGY APPROXIMATION AND SOLID-VOID INTERPOLATION SCHEMES FOR STRUCTURAL SHAPE OPTIMIZATION

DZIERZANOWSKI, Grzegorz* *Warsaw University of Technology, Poland*

In this research the following question is addressed: Having a fixed amount of material, form a structure whose compliance, i.e. the work of external loading, achieves the minimal value. Such task falls into the broader category of optimal material distribution, or shape optimization. The original problem of determining the strict division of the design area into two subdomains respectively occupied by solid and void is known to be badly posed, even though some counterexamples can be found. In general however, material density function admitting any value between 0 (void) and 1 (solid) should be taken into consideration while seeking the optimal project of a structure. In this way, porous composites are allowed as possible solutions. Mathematical background of this phenomenon is provided by the homogenization theory. One of the most important results obtained by the homogenization approach is the explicit formula for the stress energy stored in the particle of a composite material. This remark is valid for two- and three-dimensional elasticity as well as for thin plate or shallow shell theories. Moreover, in each but the latter case, the energy formula is locally optimal as it corresponds to certain microstructural layout of solid and void. Nevertheless, the numerical implementation of the exact results is hampered by the non-smoothness of stress energy functional. Indeed, if this is the case, then the constitutive formula is not unique, hence it cannot be directly inverted into the stress-displacement form which serves as a natural base for a computer-aided procedure by FEM. As a possible remedy, one may either make use of the solution to the problem of optimal layout formulated for a two-material structure, or seek the smooth, thus invertible, approximation of the energy. In the present research, the latter option is investigated. Consequently, a proposition of a constitutive relation for a porous material arise. Explicit formulae for the function describing the distribution of basic isotropic material in the design space can be derived for interpolation schemes obtained in any of the above-mentioned settings. The corresponding calculations follow the Rockafellar Theorem which, roughly speaking, allows to impose the requirement of optimality locally at each point of the design domain. Keywords: Shape optimization, Minimal compliance, Interpolation scheme

OPTIMAL SHAPING OF MIDDLE SURFACE OF A DISHED HEAD OF CIRCULAR CYLINDRICAL PRESSURE VESSEL WITH THE HELP OF BEZIER CURVE

LEWINSKI, Jerzy* *Poznan University of Technology, Poland*
MAGNUCKI, Krzysztof *Poznan University of Technology, Poland*

Dished head meridian of a pressure vessel is usually shaped in the form of thorispherical, ellipsoidal, or hemispherical surface. Such heads are commonly used in the industry. The main fault of these heads consists in stress concentration in the region of cylindrical part and head joint. The problem has been remarked for the first time by V.D. Elin and V.I. Haritonov (1977) J. Middleton (1979) and E.H Mansfield (1981). Subject of the paper is a dished head shaped with the use of the Bezier curve. Since the stress depends, among others, on the meridional curvature, radius of the curvature should be continuous. Curvature of commonly used torispherical or ellipsoidal heads is distinguished by sudden variation in the contact point of the head and cylindrical parts of the meridian. This is due to the fact that the meridional curvature radius of the cylindrical part is equal to infinity, while further course of the meridian belonging to the head is of finite radius. In order to avoid the situation the head profile should begin from infinite radius too. Such a shape of the head may be described by the Bezier curve. Principal curvature radii of the head surface are defined. First of all, a geometrical condition is formulated that imposes continuity of the curvatures in the joint between the cylindrical and head parts. The stress state of the head is determined taking into account the above geometrical condition. Another requirement that is considered as a strength condition consists in preventing the excess of maximal head stress above the level occurring in the cylindrical part. The above two conditions impose the relationships between the dimensionless parameters determining the shape of the meridian. The optimization criterion is minimum relative depth of the head under the geometrical and strength constraints. The minimum is numerically found with the help of the parameters determining the Bezier curve. In result of the study the shape of the head of minimal relative depth and the stress distribution in the head are obtained. The stress distribution is nearly uniform and approximates the stress state of the cylindrical part of the vessel. Such a vessel is almost a fully stressed one. Moreover, the elastic buckling problem and critical pressure are considered. The results are shown in figures and compared to classical ellipsoidal heads.

DESIGN OPTIMIZATION OF SPACE FRAMED STRUCTURES USING MULTIPLE CARDINALITY CONSTRAINTS

LEMONGE, Afonso Celso de Castro* *Federal University of Juiz de Fora, Brazil*
BARBOSA, Helio José Correa *LNCC, Brazil*

It is a common simplifying practice in structural optimization to group certain sizing variables (associated with members with similar function, for instance) into a single design variable. This is also done when

symmetry conditions are to be imposed in the final design. In both cases, the total number of design variables is decreased, leading to a computationally less expensive problem. In a weight minimization problem, for instance, when N sizing variables are defined, the optimum solution will likely display N different values. As N grows, the cost of the material used in the optimum solution decreases, but the difficulty of the corresponding search problem also grows. It is then clear that such grouping procedure affects the final results and that its effectiveness depends crucially on the designer's skill in allocating members/variables to a group. As a result, it would be advantageous to the designer to be able to 1) limit the number of different design parameters (such as cross-sectional areas) in order to; 2) (a) achieve economies of bulk purchasing/fabrication, and (b) simplify construction; 3) leave to the optimizer algorithm the task of deciding how to group members and/or design variables, and 4) achieve the best possible solution within the available computational budget. Objectives 1 and 2 can be achieved by introducing a cardinality constraint. Objective number 3 can only be attained with a careful formulation of the optimization problem on the part of the designer. He or she should initially group certain design variables in order to enforce the desired symmetries of the members of the structure or any other required feature by using, for example, cardinality constraints. A cardinality constraint arises naturally in structural optimization when the designer, faced with the task of selecting from a large set of commercial profiles (AISC tables, for example), wishes to employ a reduced number of distinct profiles. The computational experiments presented here involve the structural configuration of space frames and we will consider (i) mc and mg as the maximum number of distinct cross sections for columns and girders, respectively, to be defined by the user as input data, as well as (ii) additional discrete design variables corresponding to the orientation of the profiles selected for the columns.

SHAPE AND TOPOLOGY OPTIMIZATION FOR THE STRESS-BASED TRUSS DESIGN UNDER MULTIPLE LOADING

DESCAMPS, Benoît* *Université Libre de Bruxelles, Belgium*
FILOMENO COELHO, Rajan *Université Libre de Bruxelles, Belgium*

Topology optimization under single loading stands itself as one of the most powerful tool for the conceptual design of trusses. However, this optimization process converges, in general, toward continuous-like structures with many thin bars and mechanisms. As a remedy, dealing with shape parameters and multiple loading is essential for practical design; but their integration into a unified formulation is far from being solved up to now. Therefore, this contribution aims to extend our previous works on shape and topology optimization by taking into account several loading scenarios. For this purpose, let us first identify the main issues. Foremost, the definition of nodal positions as optimization variables makes the optimization problem highly nonlinear. Hence, the equilibrium formulation must be robust in order to find feasible solutions while covering the melting node effect (i.e. when two end-nodes merge), which could lead otherwise to non-differentiability in the length function. Additionally, the optimal topology inherently involves a subset of vanishing cross-sections for which stress constraints are meaningless. This singular optimum belongs to a degenerate subspace of the feasible design space. Without specific treatment, most nonlinear programming techniques fail to locate these regions. Finally, it should be mentioned that multiload problems may rapidly reach computer capacities. In order to address large-scale problems, the proposed formulation attempts to overcome the aforementioned limitations through nonlinear programming. Using the benefits of form finding methods, the static equilibrium is stated using the force density parameterization. The principle is further extended to regularize the objective function. Then, it turns out that the handling of stress constraints is actually tractable by providing high-order derivatives to the gradient-based solver. The overall problem is solved according to a simultaneous analysis and design approach. Although this formulation is usually restricted to fairly small applications, the proposed method shows good performances even for multiload problems involving several thousands of variables, thanks to a sparse interior-point solver. Numerical examples of three-dimensional configurations illustrate the methodology. Future prospects will focus on the introduction of compatibility conditions to enforce elastic design requirements.

SHAPE AND THICKNESS OPTIMIZATION OF THIN-WALLED PRESSURE VESSEL END CLOSURES

KRUZELECKI, Jacek *Cracow University of Technology, Poland*
PROSZOWSKI, Rafal* *Cracow University of Technology, Poland*

Circular cylindrical pressure vessels can be completed by different types of closures. Most pressure vessels are closed by convex torispherical (two-arc), ellipsoidal, or hemispherical (one-arc) heads. Such structural elements are, in general, standardized but they can also be manufactured as special designs. The shape of the middle surface as well as thickness of the closure can differ from those prescribed in the standards and can be optimized. Smooth and appropriately supported, axially symmetric shells under uniform pressure can be considered as structures in the membrane stress state. However, at the junction between a cylindrical shell and a vessel head, as well as between spherical and knuckle parts, there are discontinuities of meridional curvatures, which disturb the membrane stress state. The bending that occurs because of these discontinuities causes some stress concentration and influences the strength of such structures. Therefore, this paper is aimed at defining such profiles of meridians and distributions of wall thickness for which the bending state in the entire structure is minimized or eliminated. In this paper, the problem of shape and thickness optimization of thin-walled pressure vessel heads is investigated. The optimal geometry of a closure, which minimizes the design objective, contains both depth and capacity or both depth and volume of the material of a closure (two variants). This optimal geometry is explored in a broader sense under geometrical constraints within the class of uniform strength structures. In the general case, if bending cannot be eliminated, the optimal closure is a shell of uniform membrane-bending strength. Three types of optimization problems are considered: the optimal shape of the middle surface is sought for a prescribe wall thickness, the optimal wall thickness is sought for a prescribed shape of a closure, and the most general case when we desire a combination of both shape functions. The shape of a meridian is approximated either by the convex Bézier polynomial or by functions with free parameters (two- and one-arc domes). Optimal solutions are derived using a numerical optimization method, namely the simulated annealing algorithm (SA).

OPTIMIZATION OF WELDED STRUCTURES WITH HOT SPOT STRESS CONSTRAINTS EVALUATED USING CONSISTENT FINITE ELEMENT MESHING

TAKEDA, Norio* *Hitachi, Ltd., Japan*
PAPALAMBROS, Panos Y. *The University of Michigan, United States of America*

An optimal design procedure for developing light-weight welded structures is proposed in this study. When we design a welded structure subjected to a cyclic load, we have to pay attention to the fatigue failure of welded joints in the structure. The risk of fatigue failure is confirmed by comparing the stresses observed in the vicinity of the welded joints with the allowable stress. The traditional method of evaluating fatigue strength in practice is based on the use of nominal stress, which is far-field stress for a welded joint and does not include stress concentrations associated with structural details, e. g., butt joint or cruciform joint. This traditional approach does not work well in cases where finite element analysis (FEA) is used to obtain stress, because the stress obtained using FEA includes the stress concentrations. Thus, fatigue strength evaluation based on structural hot spot stress is recommended especially when using FEA. Structural hot spot stress comprises the stress concentrations of the structural details, and is estimated by extrapolating to weld toe from the stresses at reading points. The positions of the reading points correspond to those of the nodes of finite element mesh, and they depend on the thickness of the welded plate for which fatigue failure is evaluated; for example, the positions can be 0.4t and 1.0t, where t is plate thickness. This dependence of the reading points indicates that the finite element mesh should be changed due to the plate thickness when optimizing the plate thicknesses of a welded structure, even though the welded structure is modeled with shell elements. We propose a method of evaluating structural hot spot stress without changing the mesh, regardless of the plate thickness. This method makes it possible for the plate thicknesses to be optimized with constraints for structural hot spot stress. To demonstrate the effectiveness of the proposed method, the weight of a welded structure, which includes the weld details typically used for construction machinery, is minimized with structural hot spot stress constraints or nominal stress constraints. The results show that the decrease in the weight with the structural hot spot constraints is larger than that with the nominal stress constraints. This proposed procedure can contribute to develop light-weight and energy-saving products composed of welded sub-structures, such as construction machinery and trains.

STRUCTURAL OPTIMIZATION OF GEOMETRICALLY NONLINEAR TRUSSES WITH SENSITIVITY ANALYSIS OF THE PARAMETERS IN THE NEWTON-RAPHSON METHOD

SILVA, Michelli Marlane* *Programa de Pós-Graduação em Modelagem Computacional, Universidade Federal de Juiz de Fora, Brazil*
LEMONGE, Afonso Celso de Castro *Departamento de Mecânica Aplicada e Computacional, Universidade Federal de Juiz de Fora, Brazil*
BARBOSA, Helio José Correa *Laboratório Nacional de Computação Científica, Brazil*

In many types of structures, such as those often used as roofs of gymnasiums, hangars, and warehouses, the structural analysis must take into account the geometrically nonlinear behavior. This more complex analysis allows for an evaluation closer to the real behavior of the structure thus avoiding undesirable structural problems. The structural optimization problem of choosing the profile of each member belonging to a structure in order to minimize its weight while satisfying stress, displacement, stability, geometric and other applicable constraints is complicated by the requirement of considering nonlinear structural behavior. In order to provide an exact structural analysis, the equilibrium equation in each joint of the structure must be written considering the final geometry of the structure and the terms involving strain and displacement must be considered. To solve this system an iterative scheme is required and the Newton-Raphson's method is adopted here. This paper presents a sensitivity analysis of the parameters in the Newton-Raphson method, such as the number of load steps, the number of iterations, and tolerance value, when applied within a genetic algorithm, with respect to the convergence speed of the optimization process as well as the quality of the final solution found. This paper presents numerical experiments involving shallow planar trusses and dome structures with clear nonlinear behavior.

RELIABILITY BASED DESIGN OPTIMIZATION FOR NON-LINEAR STATIC TRUSS SYSTEM CONSIDERING REDUCED-ORDER MODELING

MOTTA, Renato de Siqueira* *UFPE, Brazil*
AFONSO, Silvana Maria Bastos *UFPE, Brazil*

In most engineering applications, the traditional optimization approach is to consider determinis-tic models and parameters on the design of engineering system. Unfortunately, the deterministic approach generally leads to a final design whose performance may degrade significantly or con-straints can be violated due to perturbations arising from uncertainties. In this scenario a better tar-get is an optimal design that gives a low probability of failure. The probability of failure for a spe-cific mode of failure is computed via reliability analysis. The process to find such optimal is referred to as reliability based design optimization (RBDO). In this paper, we use RBDO to obtain designs for a prescribed probability of failure. Commonly uncertainty in material properties, variation in geometry, uncertainty in loading and boundary condition, etc. are included in the design process by introducing simplified hypothesis which does not present the probability of failure. The efficient way to consider the uncertainties and to compute the probability of failure is through reliability analysis. Here, we discuss two reliability analysis method that exploit deterministic computer mod-els: Monte Carlo (MC) method and First Order Reliability Method (FORM). These approaches con-sider the computational system (code) as a black-box, which returns the reliability index and proba-bility of failure of a specific problem given its uncertainties. As the reliability analysis could be very costly, especially when using the MC method, approximation techniques based on reduced-order modeling (ROM) approach are also incorporated in our procedure via proper orthogonal decomposi-tion (POD) method. POD method will be employed to provide the surrogate model for fast nonline-ar analysis output for trusses. Such technique approximates the numerical model by reducing the total number of degree of freedom of the original problem (high fidelity (HF) model). The POD is a ROM that, basically, projects the problem into a subspace formed by a optimum orthonormal basis functions, in the sense that it consider the most significant shape (greatest variance) of the output subspace. A Structural sizing optimization (SSO) algorithm incorporating such procedure in the structural, sensitivity and reliability analyses will be used to obtain efficient optimal trusses design for a prescribed target reliability index. A case study will be presented to illustrated the developed procedure.

ELASTO-PLASTIC PARAMETER OPTIMIZATION BASED ON GRADIENT METHODS

RIBEIRO, Tiago Gonçalves* *Universiade of Brasília, Brazil*
MALCHER, Lucival *University of Brasília, Brazil*

The numerical simulation quality of the mechanical behavior of metal materials is extremely related to the correct choice of constitutive model associated, to the level of spatial discretization of the specimen, the quality of experimental tests carried out and the correct determination of elastic plastic parameters as the hardening curve of the material under study. Thus, the use of numerical optimization technique has become in recent years an essential tool to support the numerical analysis of problems in solid mechanics. The numerical response of the constitutive model is widely associated with the level of plastic strain of the material. Besides that, the correct identification of parameters that reproduce the isotropic or/and kinematic non-linear behavior of the material becomes a very important task to researchers around the world. Nevertheless, in this study seeks to develop a parameter optimization algorithm based on gradient methods, as univariate methods such as bisection and gold section, and multivariate methods such as Newton and the maximum descent. For this, the first part of the work, it is procedure a brief review on the methods cited, as well as a qualitative analysis of different curves that may represent the hardening curve of metal materials. In a second stage of this work, it is proposed strategies based on FORTRAN for numerical implementation of optimization models in the study. A academic finite element method is used for numerical solution, and the mechanical behavior of the material is described by the von Mises model with nonlinear isotropic hardening. The numerical optimizations are performed based on experimental studies available in the literature for smooth cylindrical specimens subjected to pure tension. At the end of the process are analyzed the computational cost of each method, the quality of results as well as the level and amount of so-called objective function associated with each method.

A SEMIDEFINITE PROGRAMMING ALGORITHM FOR STRUCTURAL OPTIMIZATION INVOLVING CONSTRAINTS ON THE NATURAL FREQUENCIES

BAZAN, Elmer G.* *COPPE/Federal University of Rio de Janeio, Brazil*
AROZTEGUI, Miguel *UFRN, Brazil*
ROCHE, Jean *Institut Elie Cartan de Nancy, Université de Lorraine, Nancy, Brazil*
HERSKOVITS, José *COPPE/ Federal University of Rio de Janeiro, Brazil*

We consider Semidefinite Programming (SDP) problems that deal with the minimization of an objective function and include semidefinite constraints on symmetric matrix-valued functions, as well as standard nonlinear equality or inequality constraints. When either the objective function or the constraint matrix function is nonlinear we have a nonlinear Semidefinte program. These SDP are employed in a numerical model for structural optimization with stress, displacements and natural frequency constraints. The present contribution is based in the FAIPA-SDP, an interior point algorithm that solves Karush Kuhn Tucker condition for SDP employing Newton like iterations, [1]. Structural analysis is carried out with the standard finite element method and, as usually, employing symmetric matrices to define both the stiffness and the mass matrices. Employing the particular structure of these matrices, structural analysis and optimization become much more efficient computationally. We propose a reformulation of the FAIPA-SDP that takes keeps the particular structure of matrices in FEM, improving computational effort to solve structural optimization applications. Finally, will describe the implementation for structural optimization and preseent some numerical examples solved very efficiently. [1] Aroztegui, M. "Numerical Techniques for Semidefinite Programming and Applications in Structural Optimization", Dr. Sci. Thesis, COPPE, UFRJ, Brazil, 2010,(in Protuguese).

PERFORMANCE BASED OPTIMAL SEISMIC DESIGN OF STEEL MOMENT FRAMES USING A HYBRID GENETIC ALGORITHM

CHOI, Se Woon *Yonsei University, South Korea, Korea*
Park, Hyo Seon *Yonsei University, South Korea,*

Many researches on the performance based optimal design of steel moment frames using a genetic algorithm (GA) have been performed. However, GA requires very large computation time to converge. Therefore, this study presents the performance based optimal design of steel moment frames using a hybrid GA in which a resizing algorithm module based on the displacement participation factor (DPF) is embedded in GA. A resizing algorithm module has the function to decrease the maximum inter-story drift without the increase

of structural weight because of resizing the size of elements based on the DPF. This module plays a role to efficiently exploit a local minimum solution. This method is demonstrated by application to the steel moment frame example. It is identified that the convergence speed of this method is rapider than that of pure GA and this method generates superior designs to pure GA.

INTEGRATING AUTOMATIC ZONE MODELING WITH GA IN A TWO-STEP APPROACH FOR STRUCTURAL OPTIMIZATION OF A COMPOSITE WING.

LEMOS, Vinicius Leite* *ITA, Brazil*
CASTRO, Saullo Giovani Pereira *Embraer, Brazil*
HERNANDES, Jose Antonio *ITA, Brazil*

This work is intended to present a methodology for the structural optimization of a preliminary composite wing based on automatic zone modeling strategy followed by GA iterations. The automatic zone modeling approach is based on MSC.NASTRAN topometric optimization capability in which the thicknesses of the composite layers [0º, ±45º, 90º] of each finite element are the design variables, weight minimization is the objective and buckling load factor is constrained. The zones are generated based on the gradient of the thickness and the ply percentage distribution of the panels. On a second step the resulting structure is the base of a GA optimization, in which the population is generated such that the resulting thickness is within a range around the initial design. A constraint is also imposed to guarantee a fully blended laminate solution. A comparison study is done to evaluate the effects of the zone modeling and the blending on the optimal solution. This multi-step approach seems to be adequate do generate efficient optimum laminate design for a composite wing structure.

DYNAMIC RESPONSE OPTIMIZATION OF AN AERONAUTICAL PANEL SUBJECT TO BEATING EFFECTS USING EQUIVALENT STATIC LOADS

GUERRINI FILHO, Hélio* *ITA, Brazil*
HERNANDES, Jose Antônio *ITA, Brazil*
LUCENA NETO, Eliseu *ITA, Brazil*

The structural optimization under dynamic response of structures modeled by finite element typically requires a high computational effort due to the costly dynamic response analyses required for convergence of the optimization. The transformation of dynamic load into equivalent static load (ESL), allows considerable reduction in optimization computational cost and simplifies the approach to the problem. In this work, stiffened aeronautical panels under dynamic loading, subject to constraints on nodal displacement, von Mises stress and dynamical buckling are optimized using the technique of ESL. The numerical applications show that the strategy of the ESL is able to effectively deal with the optimization of panels that are subjected to loads with high frequency noise which excite close to the natural frequency causing the phenomenon of beating in restricted dynamic displacements, producing structures that satisfy the imposed displacement and buckling constraints.

DESIGN OPTIMIZATION OF PLATE FOR BUCOMAXILOFACIAL SURGERY INCREASE MECHANICAL STRENGTH

RICARDO, Luiz Ciuccio* *UNITAU, Brazil*
VIKTOR, Pastoukhov *UNITAU, Brazil*

This paper presents an optimization study design applied to titanium plates in maxillofacial surgery. Titanium is today one of alloplastic materials most widely used due to osseointegration and is also extremely light weight, high degree of tensile strength and corrosion resistance, low thermal conductivity. The forces involved during insertion and during the service of maxillofacial plates deserve special attention, since it can cause fracture of the same leading to treatment failure. Efforts supported by plates and screws during use can be divided into efforts for integration and activation efforts. The main objective of this paper is to optimize the mechanical strength of the maxillofacial plates with respect to the efforts that they are subjected during surgical insertion. This article reports continuous improvement actions implemented to improve the mechanical performance of maxillofacial plates and screws. Were made three different configurations of plates and the difference between them was the product geometry. The mechanical strength of the product was measured by computer simulation and testing oblique loading. The results show that it is possible to obtain an increase in mechanical strength of plate types examined.

STRUCTURAL OPTIMIZATION IN CONJUNCTION WITH MODEL ORDER REDUCTION

JOKIC, Marko *University of Zagreb, Croatia*
STEGIC, Milenko *University of Zagreb, Croatia*
VRANKOVIC, Nikola* *University of Zagreb, Croatia*

A new method is presented for structural optimization of the vibration system with respect to the vibration response. Under the assumptions of asymptotic stability of the state-space system representing the structure, optimization criterion is derived from the system H-infinity norm, that is, system worst-case vibration response of the system for all steady-state sinusoidal excitations over all frequencies. The system stiffness matrix is assumed to be affine function of the optimization variables (structure stiffness parameters). The optimization algorithm is derived from the H-infinity optimization criterion, expressed in terms of bilinear matrix inequality. Such approach introduces in the method the so-called Lyapunov matrix with dimensions equal to the number of system state variables, employing additional optimization variables. Obviously, this increases the computational cost significantly, limiting the proposed optimization procedure to small-scale problems. To make the method applicable for optimization of large-scale problems, special structure of the system matrices is utilized to eliminate some of the optimization variables. Considering a reduced-order optimization procedure, the number of optimization variables can be decreased, additionally. The following procedure is proposed. For some fixed optimization variables (e. g. their initial values), a matrix containing several system mode shapes is constructed. The mode shapes are chosen such that they represent the critical structure vibration modes. Then, parameterized system matrices, i.e. matrices which are functions of optimization variables, are projected to the subspace spanned by the mode shape matrices. This results in small reduced-order parameterized system. This reduced-order optimization procedure is based on the assumption of small sensitivity of the system mode shapes with respect to optimization variables. For that reason, the system mode shapes matrix, which normally depends on the system parameters (optimization variables), is kept constant throughout the optimization procedure. This assumption may be verified a-posteriori by checking the system mode shape matrix for initial and optimal system parameters. A numerical example (a finite element model of power plant) which clearly illustrates the applicability and efficiency of the proposed procedure is studied. By applying the described optimization procedure, the system steady-state vibrations are attenuated significantly.

DEFINING ANALYTICAL RIGID CURVES AND SURFACES IN TOOL OPTIMIZATION PROBLEMS

DE-CARVALHO, Raquel* *University of Aveiro, Portugal*
ANDRADE-CAMPOS, António *University of Aveiro, Portugal*
VALENTE, Robertt *University of Aveiro, Portugal*

Inverse approaches and shape optimization procedures allied to the Finite Elements Method (FEM) are nowadays increasingly being adopted in order to solve complex mechanical plastic forming processes. The shape optimization procedures tries to find a geometry or shape that is optimal, minimizing a certain objective function while satisfying a given set of constraints. Considering the current scientific literature, the mostly described inverse problems in metal forming are those where the initial workpiece geometry varies during the optimization process. On the other hand, tool shape optimization problems are of extreme importance in the definition of the proper tools' geometry to be used, especially in multi-stage plastic forming operations, although these kind of problems are not so much evolved in the literature. In these cases, it is aimed to find the best shape of the tool, assuming the initial definition of the workpiece as constant during all the optimization process and, therefore, only changing the tool geometry. Therefore, the problem can be classified as an inverse tool shape optimization problem. In the present work, these two different approaches, the initial geometry and the tool shape optimization, are presented and compared for a specific two-stage forging example. The advantages as well as the disadvantages of both approaches are also presented. These optimization processes are carried out by means of an integration between an optimization program and a FEM software. Following this idea, the present paper also intends to explain and demonstrate how the combination of an in-house optimization code (SDL optimization software) with a commercial FEM program (Abaqus® software) is able to correctly solve some tool shape optimization problems. Furthermore, being the tool geometry definition the key-point in this sort of problems, different parametric discretization of the rigid tool are also studied, such as Bézier and NURBS curves/surfaces. Information on how they can be implemented in Abaqus® software, by means of the RSURFU Abaqus user subroutine for analytical rigid

discretization, is also given. Considering the obtained results, it is possible to conclude that both approaches can lead to good results. However, it was verified that the initial geometry optimization approaches are able to conduct to better results, when saw in terms of objective function and computational cost.

OPTIMIZATION OF ELASTIC PLASTIC CIRCULAR PLATES MADE OF HOMOGENEOUS AND COMPOSITE MATERIALS

LELLEP, Jaan *University of Tartu, Estonia*
VLASSOV, Boriss* *University of Tartu, Estonia*

Optimization of elastic plastic circular plates made of homogeneous and composite materials Jaan Lellep, Boriss Vlassov University of Tartu Institute of Mathematics Liivi Street 2, 50409 Tartu Estonia e-mail: jaan.lellep@ut.ee, boriss.vlassov@ut.ee Problems of optimization and analysis of axisymmetric bending of circular plates subjected to the distributed transverse pressure is studied. In the current paper a method of optimization of circular plates of piece wise constant thickness is developed. The material of plates is assumed to be an ideal elastic plastic material which obeys von Mises yield condition and associated flow law. The cases of plates made of a unidirectionally reinforced composite material are studied as well. It is assumed that the unidirectional composite can be considered as an orthotropic material which obeys non-linear Hill's yield condition in the range of plastic deformations. The case of the Tsai-Wu yield condition is studied as well. Using the pure bending theory of thin plates, the stress strain state of the plate is determined for the initial elastic and subsequent elastic plastic stage of deformation. When deriving necessary optimality conditions with the aid of variational methods of the theory of optimal control the method of the extended functional is employed. This results in a differential-algebraic system of equations. The latter is solved numerically. The effectivity of the design established is assessed numerically in the cases of one-and two-stepped plates.

PASSIVE VIBRATION CONTROLLERS WITH ZERO DYNAMIC REACTION

SOHOULI, Abdol R. *IDMEC, Department of Mechanical Engineering, Technical University of Lisbon, Portugal*
DIMITROVOVÁ, Zuzana* *UNIC, Department of Civil Engineering, Universidade Nova de Lisboa, Portugal*
RODRIGUES, Helder C. *IDMEC, Department of Mechanical Engineering, Technical University of Lisbon, Portugal*

Recent progress in material processing and manufacturing have motivated increased interest of the scientific community in material optimization. Tailoring material properties to achieve the optimal response to a given solicitation provides an important input to the new materials development. This contribution is focused on material model identification and posterior optimization of its material parameters characterizing non-linear behaviour in order to achieve zero dynamic reaction in passive vibration one-dimensional controller. It is assumed that a mass of a given value is connected through a passive isolator to a fixed support. The mass is excited by a time dependent set of forces. In the first step material models that allows for zero reaction is identified by analytical procedures. In the second step non-linear behaviour of the selected material model components is optimized by generic probabilistic metaheuristic algorithm simulated annealing algorithm. The design space is composed by non-linear load-displacement curve of each spring contained in the discrete material model, while all dampers are linear viscous. Dynamic stability is assured by non-decreasing load-displacement curves. The optimization procedure is programmed within MATLAB environment. Shooting method is used for steady state response determination. Sensitivity of the final design obtained is also evaluated. Final design is compared with material models involving linear negative stiffness components. In these cases the tailoring is enabled by adjusting a negative stiffness component and an additional tuning mass. The problem is formulated and solved analytically in complex space. Numerical results are evaluated in MAPLE environment. The results obtained can facilitate the design of elastomeric materials with improved behaviour in terms of dynamic stiffness. Both approaches confirm important role of quasi-zero stiffness and negative components in passive vibration control. Conclusions drawn can have a direct and immediate impact on product design and development, especially in the design of new mechanical components such as engine mounts and /or new suspension systems.

MESH OPTIMISATION FOR THE INVERSE MODELLING OF THE VICKERS TEST AND ITS APPLICATION TO A TRIBOLOGICALLY MODIFIED SURFACE LAYER

RAMÍREZ, Miguel A. *Universidad Nacional Autónoma de México, Mexico*
FIGUEROA, Carlos G. *Universidad Nacional Autónoma de México, Mexico*
JACOBO, Víctor. H. *Universidad Nacional Autónoma de México, Mexico*
ORTIZ, Armando *Universidad Nacional Autónoma de México, Mexico*
SCHOUWENAARS, Rafael* *Universidad Nacional Autónoma de México, Mexico*

Inverse modelling of indentation has aims to obtain material properties on small samples and eliminate tensile testing. Several methods proposed in literature seem to lack precision and uniqueness. When viscoplastic, anisotropic or layered materials are concerned, all published methods become invalid. To cover a wide range of properties in inverse models, efficient finite-element meshes have to be used while maintaining accuracy; these models have to be run several hundreds of times. The interaction between an elastic indentor with an elastoplastic body under conditions of frictional contact and large plastic deformation is most efficiently analysed by explicit finite element models. To achieve computational efficiency, mass or time scaling has to be used. If the acceleration factor is chosen too high, precision is lost due to dynamic effects; too large time steps also deteriorate the precision of the contact algorithms. Coarse meshes affect the contact algorithm and provoke hourglassing, but too fine meshes prove impractical as they negate the effect of time or mass scaling. To evaluate the different meshes and scaling factors, four criteria were used, of which the calculation time was self-evident. Hourglassing was checked by means of the artificial energy, while excessive acceleration was verified by comparing the kinetic energy to the total work. The most sensitive criterion was the smoothness of the load-displacement curve during the simulated test, as the latter reveals problems with mesh geometry as well as acceleration procedures. The optimal model was used to estimate the properties of a tribologically modified layer on an Al-Sn alloy. This layer, of 10-20 *m, is significantly harder than the substrate. Due to the low resolution of the FEM-mesh, only the upper three element layers can be modified. Even so, significant differences in the load-displacement curves were found for different functional gradients in this zone, as was the case for the amount of elastic recuperation, sink-in and pile-up of the material. In future experiments, the surface profile of the indented material will be determined, as this proved to be the most sensitive feature in terms of the mechanical properties of the surface layer.

OPTIMIZATION OF TRUSSED STRUCTURE CONSIDERING BUCKLING MODES

SIQUEIRA, João Márcio * *RM Soluções Engenharia Ltda., Brazil*
SILVA, Marcelo Araujo da *RM Soluções Engenharia Ltda., Brazil*
BRASIL, Reyolando *UFABC, Brazil*

The main goal of this work is to present the formulations and solutions of optimization problems of trussed structures, considering buckling modes. Several optimizations problems are formulated, first to compute the ultimate load of the structure and after that to minimize the structure mass. In the first problem the properties of the cross sections are kept constant, while in the second problem we keep constant the load and change the cross-section properties. The objective is to design lighter structures and minimizing the costs. Concepts of optimization, equilibrium, buckling and steel structures are used. As suggestion for further work we propose to impose a given probability of failure in the structure bars and minimize the structure mass.

ON THE STRUCTURAL OPTIMIZATION IN PRESENCE OF BASE ISOLATING DEVICES

GIAMBANCO, Francesco *University of Palermo - Italy*
BENFRATELLO, Salvatore *University of Palermo - Italyy*
PALIZZOLO, Luigi *University of Palermo - Italy*
TABBUSO, Pietro*. *University of Palermo - Italy*

As it is well known, in the last decades a lot of researchers addressed their efforts in order to improve the wide field of structural optimization, providing many original formulations of the optimal design as well as interesting contributions related to the computational procedures (see, e.g. [1-3]). The typical formulation depends on the choice of an appropriate objective function (usually the structural weight), on the particular load conditions to be considered (usually suitable combination of fixed, cyclic and/or dynamic loads) and on the special limiting criterion to impose on the structural behaviour. Nowadays, making reference to civil and/or industrial structures, the most studied problem is related to the search for the minimum volume of a

structure subjected to suitably chosen combinations of fixed loads, wind and seismic actions, each amplified by appropriate load multipliers, ensuring simultaneously an elastic shakedown behaviour in serviceability conditions and preventing an instantaneous collapse for high intensity loads. Unfortunately, the related search problem requires a remarkable computational effort; actually, in order to effect the elastic plastic analysis, some linear complementarity problems have to be solved within the optimum problem. With a load condition characterized by low intensity cyclic loads, or if it were possible to reduce the load effects on the structure, the optimal design could be determined imposing different limit behaviour to the structure, for example imposing just a limit state of elastic shakedown for the design. Such an occurrence would enable a low computational effort related to the solution of the search problem as well as further practical advantages related to the structure safety and maintenance. The seismic load effects on the structure can be reduced by utilizing appropriate base isolation systems (see, e.g. [4]). In this paper the optimality conditions of an elastic plastic structure equipped with a base isolation system is investigated. In particular, the seismic effects are studied by a classical modal technique and the optimal design is formulated assuming among the classical geometrical design variables even the behaviour features of the base isolation system.

System Control and Dynamic Optimization

TOWARDS OPTIMAL CONTROL OF DYNAMIC FRICTIONAL CONTACT PROBLEMS INVOLVING LARGE ELASTO-PLASTIC DEFORMATIONS

WERNER, Stefan* *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*
LEUGERING, Günter *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*
STINGL, Michael *Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*

To model the behavior of metals at high temperatures and strain rates, we use an elasto-plastic material law based on the multiplicative split of the deformation gradient into elastic and plastic parts. This constitutive theory, which is based on hyperelastic behavior in the elastic range, is combined with classical von-Mises theory as well as nonlinear isotropic hardening laws in the plastic domain. Dynamics and large deformations are important as we want to consider non-steady industrial forming processes that lead to large deviations in the final shape of the metal workpiece from the initial shape. The deformations are caused by a tool like a roll or die which is considered to be rigid here. Therefore we have to deal with a unilateral contact problem that involves Coulomb friction as the tool may have a tangential velocity. The contact problem is solved by applying an Augmented Lagrangian method to the inequality constraints for the contact stresses. The ultimate goal is to formulate an optimal control problem in such a way that a desired final state of deformation can be obtained by only controlling the trajectory of the tool. Usual box- and slope-constraints for this trajectory are considered, too. First results were obtained by using derivative-free optimization algorithms like EFOS, a Trust-Region Method for Nonlinear Optimization. Finally we discuss the use of general design sensitivity analysis (DSA) for the non-linear transient equilibrium problem combined with DSA for large deformation elasto-plasticity and large deformation frictional contact.

COMBINED TOPOLOGY AND SHAPE OPTIMIZATION OF CONTROLLED STRUCTURES

VANDYSHEV, Konstantin* *Delft University of Technology, Netherlands*
LANGELAAR, Matthijs *Delft University of Technology, Netherlands*
VAN KEULEN, Fred *Delft University of Technology, Netherlands*
VAN EIJK, Jan *Delft University of Technology, Netherlands*

Many modern mechatronic systems require speed and accuracy, which both depend on structural and control properties. It is a well-known fact, that the structure and controller designs are coupled. Therefore, traditional sequential optimization approaches, in which the structure itself is first optimized and thereafter the controller is designed, may not result in an optimal system. Chances of finding a truly optimal system can be increased if structure and controller are optimized in a simultaneous, integral optimization procedure. Our research is focusing on combining topology optimization and controller optimization. In this paper, we study the optimal design of a simplified motion control system. In particular we investigate possibilities to utilize topology optimization into integral optimization algorithm. Faster systems can be designed by using high-bandwidth controllers, which typically yield to shorter response times. However, systems with high-bandwidth controllers, may have their structural resonances exited, if the system is sensitive to noise and disturbances. This results in decreased accuracy. Therefore, the first step in this study is to increase the first eigenfrequency of the system, using topology optimization methodology. The obtained design is analysed in order to parametrize the structure with a small number of design variables. Thereafter, an integral

optimization of the system is initiated. For this purpose a nested optimization algorithm is involved. First, application of a PID-controller, involving two free parameters, is studied. The aim is to maximize a gain at low frequency, what basically results in decreasing the positioning error of the system. Finally, we find the values of structural and control parameters, at which the system shows the best possible performance. As the next step, the problem is extended to an H2-control setting, where we add floor, actuator and sensor noise. Instead of the gain at low frequency, we consider an optimal balance between control effort and positioning error by means of a Pareto curve. We present a full set of results and a detailed comparison to the PID-controller case. Insights gained from this test problem may be translated to more complex systems; specific applicability of our observations and directions for future study will be discussed in the final paper.

OPTIMIZATION FRAMEWORK FOR CONTROLLING THE SYNTHESIS PROCESS OF SILICON NANOPARTICLES

GRÖSCHEL, Michael* *Institute of Applied Mathmatics, FAU Erlangen-Nürnberg, Germany*

Solar panels currently face a new competitor arising from the future-oriented technological field of printable electronics. Conducting thin films consist in closely packed materials printed on an insulating substrate. For a large scale production in a cost effective process, highly conducting inks are required. Particles with small dimensions between 1 to 100 nanometers usually absorb light more strongly than bulk material. For an accurate arrangement, uniform and homogeneous particles are required. Therefore, the production of narrowly distributed silicon nanoparticles (SiNPs) represents an important field of research. The considered gas-phase process consists in the thermal pyrolysis of monosilane in a hot-wall reactor. The silane decomposition involves several partial reaction steps. In the reactor, the residence time of the SiNPs ranges from 80 ms to 420 ms yielding a final particle size between 10-60 nm. Commonly, only the final particle size distribution as well as the temperature profile at the reactor wall are accessible by measurements. The most important process controls to influence the system are the flow rates of silane and argon, the total pressure, and the time-temperature history of the particles in the reactor. A production rate of approximately 0.7 g/h is obtained under optimal process conditions. This corresponds to a number of 2.1e16 particles per hour assuming an average diameter of 30 nm. In this contribution the identification of new reaction conditions for the production of nearly monodisperse silicon nanoparticles is considered. For this purpose a full finite volume model for the discretization of the population balance equation (PBE) has been combined with a state-of-the-art trust-region optimization algorithm for process control. Furthermore, an optimization framework providing additional adjoint information is established. Techniques for the dynamic inversion of the considered system have rarely been investigated since the PBE is mutually coupled to a complementary mass balance. Verified against experimental data, specific process conditions are determined accomplishing a versatile range of prescribed product properties. The main achievement of the optimization is the possibility to control the different mechanisms in the particle formation process by mainly adjusting the temperature profile. Due to a successful separation of the nucleation and growth process, significantly narrower particle size distributions are obtained.

ENGINEERING OPTIMIZATION OF MULTIPLE SENSORS INTEGRATION TECHNIQUES IN MULTI-TARGET TRACKING AND DISCRIMINATION SCENARIOS

IMAM, Neena* *Oak Ridge National Laboratory, United States of America*
BARHEN, Jacob *Oak Ridge National Laboratory, United States of America*
GLOVER, Charles W. *Oak Ridge National Laboratory, United States of America*

In a dynamically evolving multi-target scenario, the ability to effectively track and identify all targets may be limited due to sensor resource constraints. In many sensor networks, sensors are heterogeneous (electro-optic, infrared, radio frequency) and provide disparate types of information based on the sensor type. A further complication is the fact that each threat/target can contain multiple objects of interest and targets can be also be very close together, thus difficult to discriminate. Therefore, optimum and intelligent management and integration of the sensors are crucial to maximizing the knowledge and value of information provided by the multi-sensor platform. Sensor Resource Management (SRM) techniques may be divided into two broad categories: myopic and non-myopic. A myopic or near-sighted SRM technique does not take into account the future impact of SRM decisions (for example, track vs. discriminate). Non-myopic or far-sighted SRM algorithms include foresight into decision planning and may discount current gains against future rewards. In this paper, we present a review of the various approaches to myopic and non-myopic sensor integration algorithms applicable to multi-sensor platforms. Myopic SRM approaches may be based on fuzzy logic and expert systems where an attempt is made to mimic human decision processes given uncertain information. Another myopic approach uses information-theoretic measures as a basis for sensor resource management where sensor control decisions are based on maximizing a particular measure of information. This information metric can be expressed in terms of an objective function. Key to good sensor integration is designing an appropriate objective function so that the sensor manager can adapt in a dynamic environment to suit the operator's needs. In this paper, we will discuss the various forms these mission value functions can take and the corresponding benefits. For non-myopic sensor integration, stochastic dynamic programming has been proposed by many researchers. SRM techniques based on Partially Observable Markov Decision Process (POMDP) are far-sighted and can include the effects of measurement and prediction uncertainty in a constantly evolving environment. In this paper, we will demonstrate the advantages/disadvantages of both myopic and non-myopic approaches to sensors integration techniques using simulation and numerical results.

DYNAMIC OPTIMIZATION USING WAVELETS BASES

SANTOS, Lizandro de Sousa* *COPPE, Federal University of Rio de Janeiro*, *Brazil*
SECCHI, Argimiro R. *COPPE, Federal University of Rio de Janeiro*, *Brazil*
BISCAIA JR., Evaristo Chalbaud *COPPE, Federal University of Rio de Janeiro*, *Brazil*

In this work we present an adaptive control vector parameterization strategy for dynamic optimization of chemical processes. The discretization technique is based on a multiresolution representation of the control vector using wavelet bases. The proposed algorithm uses an automatic procedure to refine or to coarsen the mesh in order to achieve the required accuracy minimizing the computational effort. The sequential direct approach, where only the control variables are discretized, was used to solve the optimization problem. In this approach, for a given value of the control vector, the system of differential-algebraic equations is integrated at each iteration. The optimal result of the control variables at one discretization level is used as initial guess for the optimizer at the new adapted mesh. The need to refine or coarsen the mesh depends on the dynamic process behavior that can affect the quality of approximation and consequently the discretization strategy. The method was applied to illustrative examples in order demonstrate the efficiency of the wavelets adaptation compared with conventional sequential method (uniform grids). We demonstrate that the proposed strategy is capable to identify accurate discretization meshes with low computational cost.

Topology Optimization

ENERGY CHANGE TO THE INSERTION OF INCLUSIONS ASSOCIATED TO AN ANISOTROPIC AND HETEROGENEOUS HEAT DIFFUSION PROBLEM

GIUSTI, Sebastian M.* *Universidad Tecnológica Nacional, Facultad Regional Córdoba UNT/FRC - CONICET, Argentina*
NOVOTNY, Andre A. *Laboratório Nacional de Computação Científica, LNCC/MCTI, Brazil*

The topological derivative measures the sensitivity of a given shape functional with respect to an infinitesimal singular domain perturbation. According to the literature, the topological derivative has been fully developed for a wide range of physical phenomenon modeled by partial differential equations, considering homogeneous and isotropic constitutive behavior. In fact, only a few works dealing with heterogeneous and anisotropic material behavior can be found in the literature, and, in general, the derived formulas are given in an abstract form. In this work, we present the topological asymptotic analysis for the total potential energy associated to a heterogeneous and anisotropic heat diffusion problem, when a small circular inclusion of the same nature of the bulk phase is introduced at an arbitrary point of the domain. In addition, we provide a full mathematical justification for the derived formula and develop precise estimates for the remainders of the topological asymptotic expansion. Finally, the influence of the heterogeneity and anisotropy are shown through some numerical examples of heat conductors topology optimization.

INVERSE CONDUCTIVITY PROBLEM: A BAYESIAN-TOPOLOGICAL APPROACH

ROCHA DE FARIA, Jairo* *UFPB, Brazil*
RODRIGUES DE OLIVEIRA, Luis Jonatha *LNCC, Brazil*

The inverse conductivity problem aims to estimate the unknown conductivity distribution of a body from boundary measurements: heat fluxes are injected into the body and the corresponding temperatures are measured. This problem is related to a several other applications including detecting breast cancer, monitoring of pulmonary or gastric functions, non-destructive testing and inverse problems in geophysics, etc. A number of algorithms have been developed for this problem and the majority restates the problem as a least-squares minimization problem where the cost functional is stated as a norm of the deviation between measured and expected temperature. Unfortunately this problem is ill-posed in the sense that it leads to non-unique solutions or instabilities with respect to small changes in the data. The Bayesian inference is a natural method to minimize the effects of the ill-posedness. In fact, in statistical inversion theory, the inverse problem is recast in the form of statistical quest for information which allows to takes into account priori information, model, and measurements. Then, the objective is to extract all the possible information of some of the variables based on this knowledge. Although the construction of the likelihood is the most straightforward step in statistical inversion, the majority of the approach requires simulation using Markov-chain Monte-Carlo (MCMC) methods for solving the inverse problem, that increase the computational cost of the reconstruction algorithm. In this work, we will use the topological derivative to build the likelihood function to identify inclusions in a 2D domain. The basic idea is apply topological derivative of Khon-Vogelius functional with respect to insertion an infinitesimal inclusion and identify the regions where the topological derivative is more negative with the regions of highest probability of occurrence of the inclusions. This methodology, besides giving a new interpretation for the topological derivative, avoids the need for MCMC in this case. The efficiency of this approach is presented through some numerical examples.

TOPOLOGICAL DERIVATIVE OF THE KOHN-VOGELIUS CRITERION ASSOCIATED TO THE POTENTIAL INVERSE PROBLEM

MACHADO, Thiago José* *LNCC / MCT, Brazil*
NOVOTNY, Andre A. *LNCC / MCT, Brazil*

The topological derivative measures the sensitivity of a given shape functional with respect to an infinitesimal singular domain perturbation, such as the insertion of holes, inclusions, source-terms or even cracks. This concept has been successfully applied in the treatment of a wide range of problems such as topology optimization, inverse analysis and image processing. In this work, we propose a new method for solving the potential inverse problem based on the topological derivative, which consists in the reconstruction of a source-term from boundary measurements. The basic idea is to minimize a shape functional based on the Kohn-Vogelius criterion, that measures the difference between two auxiliary problems. One of them contains information on the boundary measurement and the other one contains information on the boundary excitation. Over the solution to the inverse problem, both solutions to the auxiliaries problems coincide. Therefore, the associated topological derivative is used as a steepest-descent direction in the minimization of the Kohn-Vogelius criterion, leading toward the solution to the potential inverse problem.

TOPOLOGY DESIGN OF KIRCHHOFF PLATES BASED ON TOPOLOGICAL DERIVATIVE AND A LEVEL-SET DOMAIN REPRESENTATION CONSIDERING DIFFERENT VOLUME CONTROL METHODS

CAMPEAO, Diego E.* *LNCC, Brazil*
GIUSTI, Sebastian M. *UTN/FRC - CONICET, Argentina*
NOVOTNY, Andre A. *LNCC, Brazil*

In this work, we compare two methods of volume control in the context of topological derivative-based structural optimization. The first one is done by means of linear penalization and does not provide direct control over the required volume fraction. In this case, the penalty parameter is the coefficient of a linear term used to control the amount of material to be removed. The second approach is based on the Augmented Langrangian method which has both, linear and quadratic terms. The coefficient of the quadratic part controls the Lagrange multiplier update of the linear part. Through this last method it is possible to specify the final amount of material in the optimized structure. In order to present the behavior of both approaches, we consider the compliance topology optimization of Kirchhoff plates subjected to volume constraint. The associated topological asymptotic expansion is used in a structural design algorithm based on the topological derivative and a level-set domain representation method. Finally, some numerical experiments are presented allowing a comparative analysis between the above two methods of volume control.

TOPOLOGY SYNTHESIS OF ELECTRO-THERMAL COMPLIANT MECHANISMS USING EVOLUTIONARY OPTIMIZATION

VEGUERÍA, Estrella* *Escuela Superior de Ingenieros de Bilbao, UPV - EHU., Spain*
ANSOLA, Ruben *Escuela Superior de Ingenieros de Bilbao, UPV - EHU., Spain*
CANALES, Javier *Escuela Superior de Ingenieros de Bilbao, UPV - EHU., Spain*
TÁRRAGO, José Antonio *Escuela Superior de Ingenieros de Bilbao, UPV - EHU., Spain*

This paper describes an evolutionary topology optimization procedure for the design of compliant electro-thermal actuators. Compliant mechanisms present many advantages in connection with MEMS applications, which cannot be manufactured using typical assembly processes, and electro-thermal actuation is attractive for micro-systems design due to its large displacement and force potential. Recently, topology optimization techniques have enabled systematic design of these kinds of distributed compliant mechanisms directly from behavioural specifications. This paper describes an additive evolutionary structural optimization procedure, which has been successfully applied to several optimum material distribution problems but not for electro-thermal compliant mechanisms design. The present paper aims to progress on this work line developing an extension of this procedure and demonstrate the capabilities of the method for the more complicated case of electro-thermal actuation, based on Joule's resistive heating, where it is necessary to consider three energy domains involved, coupling electrical, thermal and elastostatic fields. The sensitivity number was derived using the first order necessary optimality conditions for the problem, and the most efficient discrete element modification is achieved adding elements which give the largest increase of the output displacement for the prescribed volume during the optimization process. A smoothing technique was used to overcome

checkerboard problems, complemented with an averaging scheme in order to stabilize the optimization process and avoid mesh dependency issues. The proposed methodology could help engineers to rapidly conceive complex and efficient actuators and enables systematic design of these devices, which can result in a save of manufacturing time and cost, providing a very simple and practical alternative design tool. Since the present investigation is based on and additive version of the evolutionary method, this approach does not have the capability to remove material but it could be combined with the classic element rejection evolutionary method to overcome these deficiencies, developing an improved bi-directional algorithm which should be analyzed and applied for these types of designs in future works. Some examples of the design of plane compliant mechanisms are presented to check the validity of this technique and the designs obtained are compared favourably with results obtained by other authors.

STRESS CONSTRAINED TOPOLOGY OPTIMIZATION OF A CANTILEVERED PIEZOELECTRIC ENERGY HARVESTER

WEOM, Fabian* *University of Erlangen-Nuremberg, Germany*
KALTENBACHER, Manfred *Alps-Adriatic University Klagenfurt, Austria*
STINGL, Michael *University of Erlangen-Nuremberg, Germany*

Vibrational piezoelectric energy harvesters are devices which convert ambient vibrational energy into electric energy by making use of the piezoelectric effect. Here we concentrate on the common cantilever type where an elastic beam is sandwiched by piezoelectric plates. Fixing the piezoelectric plates, we perform topology optimization of the elastic beam and tip mass by means of the SIMP model to maximize the electric power for a given sinusoidal vibrational excitation. We are interested in the first and especially second resonance mode. Piezoelectric coupling is a function of the mechanical straining of the device, corresponding to the stresses within the piezoelectric layers. Strain homogeneity is therefore an important issue for cantilever type harvesters and several optimization approaches in the literature are focused on strain homogenization. Based on a linear model the piezoelectric performance can also be improved by increasing the peak strain. Due to piezoceramic fragility the latter is impractical but might be advantageous for the optimizer. To this end we formulate dynamic piezoelectric stress constraints which show to be essential for obtaining utilizable results. Together with the application of a Heaviside type projection filter a practically relevant design is obtained. It is based on a mechanism which differs significantly from the common designs reported in literature.

TOPOLOGY OPTIMIZATION OF LARGE-SCALE MICHELL TRUSSES USING THE ADAPTIVE GROUND STRUCTURE APPROACH

SOKOL, Tomasz* *Warsaw University of Technology, Poland*

This paper presents a new, improved version of the program to determine the optimal Michell truss for arbitrarily defined supports and loading within a given design domain. A preliminary version of this program was presented two years ago at EngOpt2010. Since then, many improvements in the code have been implemented to obtain several times faster and more economical code with significantly reduced amount of RAM needed. Michell trusses play an important role in the theory of topology optimization of structures because they are characterized by the minimum volume of material required for the transfer of a specified load to given supports; they simultaneously determine the optimal shapes and distributions of material. In fact, they are not ordinary trusses as the number of bars in them tends to infinity - they rather define a continuum of specific orthotropic properties. Nevertheless, a good approximation for the optimal solution can be achieved through an appropriate discretization, analyzing trusses with large but finite number of bars. In this context, the traditional approach of using a fixed ground structure is attractive due to the possibility of linear programming formulation of the optimization problem but in practice it often leads to huge and intractable tasks. The adaptive ground structure approach with selective subsets of active bars can overcome this trouble. On the base of many numerical tests the improved, iterative scheme of adding-removing bars is proposed in the present paper. This improvement was achieved by adjusting of certain control and filtering parameters. In addition, the program has been significantly redesigned: a) more economical data structures have been used, b) and all crucial procedures have been rewritten to obtain a more efficient code. The current version of the program allows the analysis of the tasks on the number of potential bars of a few billion. This allows extraordinary accuracy for estimating the minimum volume of material, with a relative error not exceeding 0.001%, compared to the exact-analytical solutions. It should

be noted that the applied method guarantees finding the optimal truss from the fully connected ground structure, hence the layouts obtained in this numerical way are valuable hints of optimal frameworks. In other words the program may be considered as the useful tool for verification of results obtained in other ways and for finding new, yet unknown results in Michell truss theory.

A TOPOLOGY OPTIMIZATION METHOD TO EXTRACT OPTIMAL BEAM-LIKE, PLATE-LIKE OR SHELL-LIKE STRUCTURES FROM A SOLID FINITE ELEMENT MESH

LEIVA, Juan Pablo* *Vanderplaats Reseach and Development, Inc., United States of America*

A new topology optimization method to extract optimal beam-like, plate-like or shell-like structures from a solid finite element mesh is presented. The development of this method was motivated because traditional optimization methods tend to produce truss-like structures that are not necessarily optimal from the manufacturing point of view. Buildings, for example, are typically designed with beams and plates and not with trusses. Car bodies are designed using shell meshes because stampings are needed for enclosing the structure and for aesthetic reasons. Dams are design using walls (plate-like) to reinforce the main shell. The presented method parameterizes the design domain assembled with three dimensional solids elements. The method is suitable for general irregular meshes that are commonly produced by automatic mesh generators. The method is discipline independent and was tested on linear static and dynamic problems. The method is very efficient as it reduces the number of design variables and does not need to add additional constraints to reflect the manufacturing requirements. The manufacturing requirements are built in to the parameterization of the design variables. The proposed method is implemented in the Genesis program and examples that show its effectiveness will be included.

STRUCTURAL OPTIMIZATION OF TIMOSHENKO BEAM NETWORKS

KUFNER, Tobias* *Chair of Applied Mathematics 2, University Erlangen-Nuremberg, Germany*
STROHMEYER, Christoph *Chair of Applied Mathematics 2, University Erlangen-Nuremberg, Germany*
STINGL, Michael *Chair of Applied Mathematics 2, University Erlangen-Nuremberg, Germany*

The goal of this work is the simulation and optimization of the deformation of large 3D beam networks exposed to external loads. The optimization shall be based on the ground structure approach known from truss topology optimization. Motivated by industrial applications, the underlying beam model has to allow for effects like transport of momentum, shear deformation as well as curved geometries. On the other hand, due to the potentially large number of bars in the ground structure fast computation of the deformation field of the network by means of numerical simulation is mandatory. In order to achieve this, a 3D-Timoshenko beam model with element-wise analytical basis functions has been implemented. The numerical results generated by this approach are validated against results using linear basis functions with different global refinements of the beam elements. On the basis of the Timoshenko beam network model, various structural optimization problems are posed and numerical results are shown. The first example is a continuous sizing optimization of the beam network elements based on a given ground structure with a resource constraint and compliance as objective function. Further examples include topology and multi-material optimization. To approximate discrete solutions in these cases, the candidate materials (e.g. material-void configurations or several materials chosen from a catalogue) are parameterized using a discrete interpolation scheme such as SIMP. In case of multi-material optimization, this approach is known as the Discrete Material Optimization (DMO). Some other objective functions and constraints (like displacement constraints) are investigated as well.

TOPOLOGY OPTIMIZATION OF ROBUST SUPERHYDROPHOBIC SURFACES

CAVALLI, Andrea* *DTU Nanotech, Denmark*
ANDERSEN, Nis Korsgaard *DTU Nanotech, Denmark*
SØGAARD, Emil *DTU Nanotech, Denmark*
BØGGILD, Peter *DTU Nanotech, Denmark*
TABORYSKI, Rafael J. *DTU Nanotech, Denmark*
OKKELS, Fridolin *DTU Nanotech, Denmark*

In this talk topology optimization is applied for the first time to the design of superhydrophobic surfaces. Superhydrophobicity (extreme water repellency) is observed in nature on surfaces covered by micrometric protrusions, such as the leaves of the Lotus plant [1]. The general understanding is that water drops are suspended on these protrusions, in a so-called "fakir" state, and therefore are able to roll off very easily.

Several similar surfaces have been artificially realized in recent years, and one of the main performance issues is assuring the liquid remains suspended on the texture even if the drop is perturbed (for example by an external pressure). We therefore optimize the shape of micrometric pillars to offer the best support to a drop sitting on them. This condition is modeled by minimizing the penetration of liquid between the pillars under an applied pressure, which could arise, for example, when a drop impacts on the surface with finite velocity. We will point out how this problem can be closely related to an optimal heat conduction one, underlining analogies between the formulations and solutions. Our implementation combines a FEM model of the physics of the system (using the software Comsol3.5a) to a Matlab topology optimization code that relies on the method of moving asymptotes (MMA) [2]. Preliminary fabrication results for the optimized structures will also be shown, proving the feasibility of the optimal designs. [1] de Gennes et al, Capillarity and wetting phenomena: drops, bubbles, pearls, waves, Springer, 2004 [2] Olesen L.H. et al, A high-level programming-language implementation of topology optimization applied to steady-state Navier-Stokes flow, Int. J. Numer. Meth. Engng 2006; 65 975-1001

COMPLIANCE MINIMIZATION USING 3D TOPOLOGY OTIMIZATION METHOD WITH H-ADAPTIVE REFINEMENT

AROZTEGUI, Miguel *UFRN, Brazil*
ARANTES, João Carlos* *UFRN, Brazil*

The topology optimization problem characterizes and determines the optimum distribution of material into the domain project. The objective of this work is to propose a competitive formulation for optimum structural topologies determination in 3D problems followed by an h-adaptive refinement step in formulation of compliance minimum problems and able to provide high-resolution layouts. The finite element mesh, employed in each layout optimization problem, was obtained from the solution of the previous mesh, followed by the application of an h-adaptive refinement scheme. The procedure combines the Galerkin Finite Elements Method with the optimization method, searching to improve the material distribution along the fixed domain of project. The finite element used for the approach is a four nodes tetrahedron with a selective integration scheme, which interpolates not only the components of the displacement field but also the relative density field. According to mentions above, the proposed consist in the formulation of a compliance topology optimization problem. The Layout Optimization Method is based on approach material with considers homogenized constitutive equation that depends only of the relative density of the material. The microstructure used in this procedure was the SIMP (Solid Isotropic Material with Penalty). The approach reduces considerably the computational cost, showing to be efficient and robust. The results provided a well-defined structural layout, with a sharpness distribution of the material and a boundary condition definition. The layout quality was proportional to the medium size of the element and a considerable reduction of the project variables was observed due to the tetrahedral element.

POWER FLOW ANALYSIS BASED DYNAMIC TOPOLOGY OPTIMIZATION OF VIBRATIONAL STRUCTURES

XUE, Xiaoguang* *National university of defense technology, China*
LI, GUoxi *National university of defense technology, China*
XIONG, Yeping *University of Soutnampton, United Kingdom*
GONG, Jingzhong *National university of defense technology, China*

This paper presents a power plow analysis based dynamic topology optimization of vibrational structures. Up to now, work on topology dynamic optimization of engineering structures for vibration suppression has mainly addressed the maximization of eigenfrequencies and gaps between consecutive eigenfrequencies of free vibration, and minimization of the dynamic compliance subject to harmonic loading on the structure. In this paper, we deal with topology optimization problems formulated directly with the design objective of minimizing the transmitted energy from one part of a structure body and another. Based on the governing equations of continuum mechanics, a power flow analysis of vibrational structures is presented. In developing the mathematical model, the concept of an energy flow density vector is introduced. The structural vibrations are excited by time-harmonic external mechanical loading with prescribed frequency and amplitude. A density based topology optimization method is developed for power flow problems in steady state using an adjoint design sensitivity analysis (DSA) method. Design variables are parameterized using Bi-material Solid Isotropic Material with Penalization (SIMP) models and Method. The structural

damping is considered as Rayleigh damping. The method of Moving Asymptotes (MMA) is applied for design updating. The influences of the excitation frequency, the material density and the structural damping on optimum topologies are investigated by numerical examples.

TOPOLOGY OPTIMIZATION IN TWO-DIMENSIONAL GRANULAR CRYSTALS

SILVA SOHN, Mariana* *University of Illinois at Urbana-Champaign, United States of America*
TORTORELLI, Daniel *University of Illinois at Urbana-Champaign, United States of America*
SZELENGOWICZ, Ivan *California Institute of Technology, United States of America*
DARAIO, Chiara *California Institute of Technology, United States of America*

Granular crystals are known to exhibit interesting properties stemming from the nonlinear contact interactions between two adjacent particles. Extensive research has been carried on one-dimensional chains of homogeneous and heterogeneous spherical beads. However, the wave propagation in two-dimensional granular crystals remains relatively unexplored. Under normal conditions of impact, an uncompressed two-dimensional square packing behaves as a pseudo one-dimensional system. However, when an intruder (defect particle) occupies an interstitial site in the wave propagation path, we observe a redirection of the primary wave into secondary directional waves. This highly directional response can be used as a basis to design granular crystals with predetermined wave propagation paths capable of mitigating stress wave energy. To these ends, we propose a topology optimization scheme to tailor the energy propagation in two-dimensional granular crystals under impact loads. In our model, we place one spherical intruder in each interstitial site. As in traditional topology optimization schemes, we use a volume fraction to characterize the presence (or absence) of the intruder. We investigate different approaches to penalize intermediate values for the volume fraction, including the Solid Isotropic Material with Penalization (SIMP) approach. The goal of our transient topology optimization scheme is to find the distribution of intruders in the domain that minimizes (dispersion) or maximizes (focus) the energy in a prescribed area of the domain. We validate our numerical optimized results with experimental data. The experimental setup is composed of a polycarbonate base and four movable delrin walls to support the particles. We assemble a 20 by 20 square packing of spherical stainless steel beads. The intruders consist of custom made spheres that fit exactly in the interstitial sites. In order to have all the centers of mass of the beads in one horizontal plane, the intruders are placed on cylindrical PTFE stands to minimize friction. Experimental data is collected using mini tri-axial accelerometers embedded in selected beads, as well as piezo-sensors at the wall. Experimental results appear to be in very good agreement with the numerical ones.

FORCE FLOW METHOD IN TOPOLOGY DESIGN OF STRUCTURES

ROSKO, Peter* *Vienna University of Technology, Austria*

The contribution deals with optimal topology design of structures in statics. The basic idea of the topology design strategy is model of the “force flow” - the optimal way of original external force through the structural body to the supports. The optimal topology design of structure with static loading uses the analogy between stress distribution and fluid flow. The regular mesh of nodes is created in the original structure. (Note: by the advanced optimal design is the mesh adapted according the geometry of the structure). Each path from point where the external force acts to the support of the structure through nodes represents a string. The path is possible through the nodes only. Strings are variables of genetic algorithm. The length of strings from the structural model is generally not equal. The path between nodes of one string can be occupied by path of another string. These features require modification of the genetic algorithm. The optimization problem is defined as follows: Objective is the maximum stiffness and minimum mass. Constrains are chosen according the limit stress and maximum displacement. The presented “Force Flow Method” has applications in civil engineering and mechanical engineering showed in paper.

DESIGN OF STRUCTURES CONSIDERING NONLINEAR ELASTIC DEFORMATION USING TOPOLOGY OPTIMIZATION METHOD

LAHUERTA, Ricardo Doll* *Escola Politécnica da USP, Brazil*
SILVA, Emílio Carlos Nelli *Escola Politécnica da USP, Brazil*
SIMÕES, Eduardo *Escola Politécnica da USP, Brazil*
CAMPELLO, Eduardo *Escola Politécnica da USP, Brazil*
PIMENTA, Paulo de Mattos *Escola Politécnica da USP, Brazil*

The Topology Optimization Method (TOM) is a numerical method capable of synthesizing the basic layout of a mechanical structure accomplishing to a given design requirement, for example the maximum strain energy allowed in the structure. So far, most papers dealing with the method have been concerned with the optimization of structures with linear behavior. Even now a small number of works and articles have been concerned with the modeling and topology optimization of structures undergoing nonlinear effects. A common approach is to neglect all internal forces of the nodes surrounded with void elements during the nonlinear equilibrium iteration criterion and to delete void elements. Thus, this work proposes to study the design of structures considering exact kinematics using Topology Optimization Method (TOM) based on Solid Isotropic Microstructure with Penalization (SIMP) material model. In this work all internal forces of the nodes surrounded with void elements are considered during the nonlinear equilibrium iteration criterion and no void element is deleted. The problem of void elements is solved by considering an adequate constitutive model to solve the material instabilities which allows the material to reappear during the design process iteration. Updated consistent tangent stiffness matrix is used, which improve the convergence ratio. The Saint-Venant Kirchhoff constitutive model is compared to the proposed constitutive model during the TO design process. The variational problem is solved by the Finite Element Method (FEM). The static equilibrium of the structure is obtained by using an incremental and iterative Newton Method. The end compliance objective function is tested by minimizing it for a fixed load and the sensitivity is obtained by using the adjoint method and the material optimization distribution problem is solved through Method of Moving Asymptotes (MMA). The nonlinear projection function is implemented to obtain checkerboard-free and mesh-independent designs and to improve the convergence results. Two-dimensional results are presented and compared with previous results in the literature to show the improvement.

COMPUTATIONAL AND EXPERIMENTAL VALIDATION OF HEAT SINK DESIGN OBTAINED BY USING TOPOLOGY OPTIMIZATION METHOD

LIMA, Cícero Ribeiro de* *UFABC, Brazil*
LOPES, Edson Comini Clemente *UFABC, Brazil*
VILLA NOVA, Hélcio Francisco *UNIFEI, Brazil*
KOGA, Adriano Akio *USP, Brazil*
SILVA, Emílio Carlos Nelli *USP, Brazil*

Small scale channel systems have been studied for various applications. It consists in an innovative technology which has been applied as alternative to increase cooling efficiency of small electronic devices, such as high-end microprocessors of CPUs. This work presents a methodology for designing optimal channel systems, which can be applied to micro-channel heat sinks, for example. Here, the complete cycle development of an optimized heat sink designed by using Topology Optimization Method (TOM) is proposed, including minimization of pressure drop in fluid flow and maximization of heat dissipation effects, aiming small scale applications. The TOM carries out the distribution of a limited amount of material, inside a design domain, to obtain an optimized channel topology, according to a given multi-objective function that combines pressure drop minimization and heat transfer maximization. One of the great advantages of the TOM is the possibility of analyzing a much wider range of solutions, due to the "free" material distribution method. Thus, "not-so-intuitive" solution can be recovered using this method. This work considers Stokes flow which models incompressible flow of viscous Newtonian fluids. Moreover, both conduction and forced convection effects are included in the steady-state heat transfer model. The topology optimization procedure applies the Finite Element Method (FEM) to carry out the physical analysis, and Sequential Linear Programming (SLP) as the optimization algorithm. Two-dimensional results of optimal channel layouts obtained for a heat sink design problem are presented as example to illustrate the methodology proposed in this work. Computational simulations and experimental characterization of heat sink prototypes have been carried out to validate the results of the implemented topology optimization algorithm and the proposed design methodology.

BAND GAP DESIGN OF PIEZOCOMPOSITE MATERIALS BY USING TOPOLOGY OPTIMIZATION METHOD

SILVA, Emílio Carlos Nelli* *Polytechnic School of University of Sao Paulo, Brazil*
VATANABE, Sandro Luis *Polytechnic School of University of Sao Paulo, Brazil*

Composite materials, such as phononic crystals (PCs), can exhibit phononic band gaps, within which sound and vibrations at certain frequencies do not propagate. In fact, PCs with large band gaps are of great interest for many applications, such as transducers, elastic/acoustic filters, noise control, and vibration shields. Previous work in the field concentrated on PCs made of elastic isotropic materials; however, band gaps can be enlarged by using non-isotropic materials, such as piezoelectric materials. Because the main property of PCs is the presence of band gaps, one possible way to design structures which have a desired band gap is through topology optimization. Thus, in this work, the main objective is to maximize the width of absolute elastic wave band gaps in piezocomposite materials designed using topology optimization based on Solid Isotropic Microstructure with Penalization (SIMP) material model. To that effect, the finite element analysis is implemented with the Bloch-Floquet theory to solve the dynamic behavior of two-dimensional piezocomposite unit cells. The distribution of densities is solved through Method of Moving Asymptotes (MMA). High order modes are also investigated. The results demonstrate that phononic band gaps can be designed by means of the present methodology.

A SEQUENTIAL PIECEWISE LINEAR PROGRAMMING ALGORITHM FOR TOPOLOGY OPTIMIZATION

GOMES NETO, Francisco de Assis Magalhães *Unicamp, Brazil*
SENNE, Thadeu Alves* *Unicamp, Brazil*

In the last years, Topology Optimization has been broadly applied in the automotive and aerospatial industries, and in a special kind of structure, named compliant mechanisms. Usually, topology optimization problems are converted to nonlinear programming problems, and, in general, they are solved using methods that require only the first derivatives of the objective function and constraints. Most papers on topology optimization consider that the strain-displacement relation is linear. This is a good approximation for structures in which the displacements are small. However, it is not always valid as, for example, for compliant mechanisms, where the displacements are usually large, implying that the relation between deformations and displacements is nonlinear. In this case, we say that the structure is under a geometrically nonlinear behavior. Under small displacements, the computation of the objective function requires the solution of one linear system for structures and two linear systems for compliant mechanisms. On the other hand, when large displacements are considered, we need to solve a nonlinear system for structures and two nonlinear systems for compliant mechanisms. Due to the high computational effort imposed on the resolution of these nonlinear systems at each iteration of the optimization method, the number of papers that deal with structures under large displacements is small. Recently, Gomes and Senne presented a globally convergent Sequential Linear Programming (SLP) method that can be used to solve topology optimization problems. The goal of this work is to solve topology optimization problems of structures and compliant mechanisms under large displacements, incorporating some kind of second order information of the functions. The new optimization method, named Sequential Piecewise Linear Programming (SPLP), requires only the resolution of convex piecewise linear programming subproblems, where information about the diagonal of the Hessian matrices of the functions is used. These subproblems are converted to linear programming ones, so the overall computational cost of the algorithm is kept under control. We present some computational tests showing that SPLP is a competitive alternative to the SLP in relation to the time spent to solve the problems.

Index